भारतीय आधुनिक शिक्षा राष्ट्रीय शैक्षिक अनुसंधान और प्रशिक्षण परिषद् की एक त्रैमासिक पत्रिका है। इस पत्रिका का मुख्य उद्देश्य है शिक्षकों, शिक्षक-प्रशिक्षकों, शैक्षिक प्रशासकों तथा शोधकर्ताओं को एक मंच प्रदान करना, शिक्षा के विभिन्न आयामों जैसे—शिक्षादर्शन, शिक्षा मनोविज्ञान, शिक्षा की समकालीन समस्याएं, पाठ्यक्रम एवं प्रविधि संबंधी नवीन विकास, अंतरराष्ट्रीय स्तर पर शिक्षा का स्वरूप, विभिन्न राज्यों में शिक्षा की स्थिति आदि पर मौलिक तथा आलोचनात्मक चिंतन को प्रोत्साहित करना और शिक्षा के क्षेत्र में सुधार और विकास को बढ़ावा देना।

लेखकों द्वारा व्यक्त किए गए विचार उनके अपने हैं तथा ये किसी भी प्रकार परिषद् की नीतियों को प्रस्तुत नहीं करते।

प्रकाशन सहयोग

पूरन चंद *अध्यक्ष,* प्रकाशन प्रभाग

मीरा कांत *संपादक*

कल्याण बैनर्जी *उत्पादन अधिकारी*

अरुण चितकारा *सहायक उत्पादन अधिकारी*

राजेश पिप्पल *उत्पादन सहायक*

मूल्य एक प्रति : 8.50 रुपये; वार्षिक : 34.00 रुपये

भारतीय आधुनिक शिक्षा

वर्ष : 16 | अंक : 4 | अप्रैल 1999

विषय सूची

भारत में स्मार्ट स्कूलों की स्थापना : प्रश्न चिह्न और चुनौतियां	1	अमर नाथ माहेश्वरी
बौद्धिक उद्वेलन	8	जमनालाल बायती
प्राचीन यूनानी शिक्षा-दर्शन और वर्तमान में उसकी प्रासंगिकता	16	बी.पी. सिंह प्रदीप कुमार पांडेय गीता सिंह
कक्षा के बाहर की शिक्षा	24	सत्य नारायण पंवार
छात्रों में राष्ट्रीय एकता के भाव उत्पन्न करने के उपाय	29	राम सूरत त्रिपाठी
प्रयुक्त उत्तर पुस्तिकाओं की संख्या का निष्पत्ति पर प्रभाव : एक अध्ययन	33	सुभाष चंद्र अग्रवाल सुषमा तिवारी
शैक्षिक विकास के प्रगतिशील सोपान	40	रमेश चंद्र पारीक
उच्च शिक्षा में गुणात्मक सुधार	47	अमरनाथ दत्त गिरि

भारत का संविधान

उद्देशिका

हम, भारत के लोग, भारत को एक [1][संपूर्ण प्रभुत्व-संपन्न समाजवादी पंथनिरपेक्ष लोकतंत्रात्मक गणराज्य] बनाने के लिए, तथा उसके समस्त नागरिकों को :

सामाजिक, आर्थिक और राजनैतिक न्याय,
विचार, अभिव्यक्ति, विश्वास, धर्म
और उपासना की स्वतंत्रता,
प्रतिष्ठा और अवसर की समता

प्राप्त कराने के लिए,
तथा उन सब में
व्यक्ति की गरिमा और [2][राष्ट्र की एकता
और अखंडता] सुनिश्चित करने वाली बंधुता
बढ़ाने के लिए

दृढ़संकल्प होकर अपनी इस संविधान सभा में आज तारीख 26 नवंबर, 1949 ई0 को एतद्द्वारा इस संविधान को अंगीकृत, अधिनियमित और आत्मार्पित करते हैं।

1. संविधान (बयालीसवां संशोधन) अधिनियम, 1976 की धारा 2 द्वारा (3.1.1977 से) "प्रभुत्व-संपन्न लोकतंत्रात्मक गणराज्य" के स्थान पर प्रतिस्थापित।
2. संविधान (बयालीसवां संशोधन) अधिनियम, 1976 की धारा 2 द्वारा (3.1.1977 से) "राष्ट्र की एकता" के स्थान पर प्रतिस्थापित।

भाग 4 क

मूल कर्तव्य

51 क. **मूल कर्तव्य** — भारत के प्रत्येक नागरिक का यह कर्तव्य होगा कि वह —

(क) संविधान का पालन करे और उसके आदर्शों, संस्थाओं, राष्ट्र ध्वज और राष्ट्र गान का आदर करे;

(ख) स्वतंत्रता के लिए हमारे राष्ट्रीय आंदोलन को प्रेरित करने वाले उच्च आदर्शों को हृदय मे संजोए रखे और उनका पालन करे;

(ग) भारत की प्रभुता, एकता और अखंडता की रक्षा करे और उसे अक्षुण्ण रखे;

(घ) देश की रक्षा करे और आह्वान किए जाने पर राष्ट्र की सेवा करे;

(ङ) भारत के सभी लोगों में समरसता और समान भ्रातृत्व की भावना का निर्माण करे जो धर्म, भाषा और प्रदेश या वर्ग पर आधारित सभी भेदभाव से परे हो, ऐसी प्रथाओं का त्याग करे जो स्त्रियों के सम्मान के विरुद्ध हैं;

(च) हमारी सामासिक संस्कृति की गौरवशाली परंपरा का महत्व समझे और उसका परिरक्षण करे;

(छ) प्राकृतिक पर्यावरण की जिसके अंतर्गत वन, झील, नदी, और वन्य जीव हैं, रक्षा करे और उसका संवर्धन करे तथा प्राणि मात्र के प्रति दयाभाव रखे;

(ज) वैज्ञानिक दृष्टिकोण, मानववाद और ज्ञानार्जन तथा सुधार की भावना का विकास करे;

(झ) सार्वजनिक संपत्ति को सुरक्षित रखे और हिंसा से दूर रहे;

(ञ) व्यक्तिगत और सामूहिक गतिविधियों के सभी क्षेत्रों में उत्कर्ष की ओर बढ़ने का सतत प्रयास करे जिससे राष्ट्र निरंतर बढ़ते हुए प्रयत्न और उपलब्धि की नई ऊंचाइयों को छू ले।

भारत में स्मार्ट स्कूलों की स्थापना : प्रश्न चिह्न और चुनौतियां

अमर नाथ माहेश्वरी

संयुक्त निदेशक
एन.सी.ई.आर.टी.
नई दिल्ली

ज्ञानवृद्धि की गति तथा कार्यस्थल की बदलती हुई प्रकृति के अनुरूप विद्यालय व्यवस्था को संगत बनाने का एक प्रयास है स्मार्ट स्कूल। लेखक के अनुसार अपने मिशन को पूरा करने के लिए ये स्कूल कंप्यूटर, इंटरनेट व वीडियो कांफ्रेंसिंग जैसी शिक्षण तकनीकों का इस्तेमाल करते हैं। इसके विद्यार्थी एक दूसरे के प्रतियोगी नहीं सहयोगी होते हैं।

सूचना तकनीक (आई.टी.) तथा संचार तकनीक में आधुनिकतम विकास के फलस्वरूप विश्व के विभिन्न देशों विशेषकर आस्ट्रेलिया, जापान, मलेशिया, सिंगापुर तथा संयुक्त राज्य अमेरिका में स्मार्ट स्कूल खोले गए हैं। स्मार्ट स्कूल के संबंध में प्रत्येक देश का दृष्टिकोण भिन्न है फिर भी उनके मिशन के लक्ष्य एक जैसे हैं। स्मार्ट स्कूल, कार्यस्थल की बदलती हुई प्रकृति के अनुरूप विद्यालय व्यवस्था को संगत बनाने का प्रयास है। सूचना और संचार तकनीक का प्रयोग, सामूहिक प्रयास और आपसी सहयोग आधुनिक कार्यस्थल के ऐसे विशिष्ट लक्षण हैं जो समय सीमा और अंतर्राष्ट्रीय सीमाओं के बंधन से परे हैं। विज्ञान और तकनीक में उन्नति की वजह से व्यवसाय भी बदल रहे हैं तथा व्यावसायिक कार्यों के लिए नए-नए कौशल आवश्यक हो गए हैं। प्रत्येक व्यक्ति को नया कार्य संपन्न करने के लिए अपनी कार्यकुशलताओं को अद्यतन करना होगा। इसलिए ज्ञानवृद्धि की गति के साथ चलने तथा कार्य के स्वरूप में परिवर्तन को ध्यान में रखते हुए प्रत्येक व्यक्ति को आजीवन विद्यार्थी बने रहना होगा।[1]

आजीवन विद्यार्थी बने रहने के लिए यह आवश्यक है कि वह व्यक्ति और अधिक जानने के लिए सदैव जिज्ञासु बना रहे। अधिगम कला में, 'लर्निंग टु लर्न' में सतत प्रवीणता लाता रहे। इस संदर्भ में विद्यालय-कार्यकलापों का केंद्र बिंदु अध्यापक से खिसक कर विद्यार्थी की ओर चला जाता है। विद्यार्थियों को पहले से कहीं अधिक सीखने की ज़िम्मेदारी निभानी होगी और एक स्वायत्त

विद्यार्थी की भांति कार्य करना होगा। दूसरे शब्दों में, विद्यालयों में शिक्षण अधिगम प्रक्रम में ज्ञानवर्धन के तरीकों को उस ओर ले जाना होगा जहां विद्यार्थी प्रश्न पूछकर, पढ़कर, खोजबीन करके, सोच-विचार कर, परिकल्पनाओं का क्रियान्वयन और परीक्षण करके अपना ज्ञानवर्धन कर सके और जो कुछ भी उसने सीखा है और जिन कौशलों का उसने अभ्यास किया है उनके संबंध में अपने विचार प्रस्तुत कर सके।[2]

स्मार्ट स्कूल इस आधार पर संचालित होते हैं कि सभी विद्यार्थियों में सीखने और प्रगति करने की योग्यता है और इस योग्यता को उपयुक्त शिक्षण तकनीकों के माध्यम से और अधिक बढ़ाया जा सकता है। कंप्यूटर, इंटरनेट तथा अन्य उच्च स्तरीय संचार तकनीकें जैसे वीडियो-कांफ्रेंसिंग कुछ ऐसी शिक्षण तकनीकें हैं जिन्हें स्मार्ट स्कूल अपने मिशन को पूरा करने के लिए इस्तेमाल करते हैं। इसलिए स्मार्ट स्कूल की कक्षाएं कंप्यूटर, आपसी सहयोग तथा संरचनात्मकता के विशिष्ट गुणों से युक्त होती हैं। स्मार्ट स्कूल का एक अन्य प्रमाणक यह है कि इसके विद्यार्थी आपस में प्रतियोगी होने के बजाय एक दूसरे के सहयोगी होते हैं। स्मार्ट स्कूल की यह विचारधारा, विद्यालय में प्रत्येक विद्यार्थी को एक समान गति से पूर्वनिर्धारित शिक्षा प्रदान करने की परंपरागत भूमिका के बिलकुल विपरीत है।

स्मार्ट स्कूल की उत्पत्ति की संकल्पना प्रत्येक देश में, जहां भी इन्हें स्थापित किया गया, अलग-अलग है। उदाहरण के तौर पर सिलिकन वैली, कैलिफोर्निया, यू.एस.ए. के स्मार्ट स्कूल स्मार्ट वैली की इस धारणा के परिणाम थे कि यदि वे अपने बच्चों के विद्यालयों में सहभागी नहीं बनेंगे तो उनके बच्चे बहुत बड़ी संख्या में विदेशों को चले जाएंगे। सिलिकन वैली में पढ़ने वाले उनके बच्चे, उन कंपनियों में नौकरी पाने से अयोग्य रह जाएंगे जिन्होंने सिलिकन वैली को बनाया। आज के रोज़गारोन्मुखी बाज़ार में, कंप्यूटर कौशल, रचनात्मक समस्या समाधान की क्षमता तथा सहभागिता की योग्यताएं अनिवार्य कौशल हैं किंतु वर्तमान विद्यालय पाठ्यचर्या किसी और ही कार्यसूची पर आधारित है। अतः विद्यालयों में सूचना तंत्र तथा ऐसे साधनों की उपलब्धि अनिवार्य है जिनसे उनके विद्यार्थियों में इन कौशलों का विकास किया जा सके। स्मार्ट वैली ने यह महसूस किया कि "हम एज़्बेस्टॉज़ को नहीं बदल सकते या छतों की मरम्मत नहीं करवा सकते किंतु हम विद्यालयों में तकनीक उपलब्ध करवाने का कार्य तो शीघ्र ही पूरा करके यह सुनिश्चित कर सकते हैं कि विद्यार्थियों के पास उपयुक्त साधन हों और अध्यापकों को उनकी आवश्यकतानुसार प्रशिक्षण तथा सहयोग मिले।"

सिंगापुर सरकार का अपने स्मार्ट स्कूल के संबंध में दृष्टिकोण इस वाक्य से स्पष्ट है कि "भविष्य में जो कौशल अपेक्षित हैं वे विचार कौशलों, अधिगम कौशलों तथा संचार कौशलों पर केंद्रित होने चाहिए। सूचना तकनीक पर आधारित अध्यापन और अधिगम हमारे बच्चों में इन कौशलों को उत्पन्न करने की मुख्य कार्यनीतियों में से एक होगी।" सिंगापुर सरकार ने शिक्षा में तकनीक की मुख्य योजना के क्रियान्वयन के लिए 1977 से

2002 तक की अवधि के लिए 2 बिलियन सिंगापुरी डॉलर का प्रावधान किया है। इस निधि का प्रयोग कंप्यूटर खरीदने, विद्यालयों का नेटवर्क बनाने, भौतिक-नवीकरण, सॉफ्टवेयर, भवन, पाठ्यक्रम तथा अध्यापकों के प्रशिक्षण पर खर्च के लिए किया जाएगा। इससे संबंधित भावी रख-रखाव के लिए भी प्रतिवर्ष 600 मिलियन सिंगापुरी डालर का प्रावधान रखा गया ताकि कार्यक्रम जारी रहे। इसका मुख्य लक्ष्य यह है कि विद्यार्थियों की पाठ्यचर्या के समय का 30% समय कंप्यूटर पर कार्य करते हुए प्रयुक्त हो। वहां की सरकार की यह योजना है कि वर्ष 2002 तक हर दो विद्यार्थियों को एक कंप्यूटर उपलब्ध कराया जाए। सिंगापुर की मुख्य योजना के चार शीर्षस्थ लक्ष्य हैं :

- ❑ विद्यालय और इसके चारों ओर की दुनिया के बीच अंतर्संबंधों को बढ़ावा देना जिससे अधिगम परिवेश में विस्तार तथा संवर्धन हो सके,
- ❑ सृजनात्मक विचारधारा, आजीवन अधिगम तथा सामाजिक दायित्व को बढ़ावा देना,
- ❑ शिक्षा में नवाचारी प्रक्रियाएं उत्पन्न कराना,
- ❑ शिक्षा प्रणाली में प्रशासनिक तथा प्रबंधन की उत्कृष्टता को बढ़ावा देना।

अपने स्मार्ट स्कूलों के संबंध में मलेशिया सरकार का दृष्टिकोण यह है कि "मनुष्य को अधिगम के एकरस व असृजनात्मक पहलुओं से मुक्त करें और तारों के माध्यम से अधिगम की साइबर-दुनिया में अधिगम हेतु सक्षम बनाएं।" इनकी परियोजना में इस बात पर बल दिया गया है कि "2020 के अंत तक देश के सभी 10,000 विद्यालय स्मार्ट स्कूल बन जाएंगे।"

विक्टोरिया, आस्ट्रेलिया में सरकार ने सूचना तकनीक के साथ समाज के सम्मुख आने वाली संभावनाओं और चुनौतियों, दोनों को बहुत पहले ही पहचान लिया है। जैसे-जैसे समाज सूचना युग की ओर बढ़ता जाता है, वैसे-वैसे शिक्षा के सभी पहलुओं, विशेषकर विद्यार्थी अधिगम की गुणवत्ता को बढ़ाने के लिए विद्यालयों में संचार और मल्टीमीडिया की कार्यनीति का उपयोग होना चाहिए। विक्टोरिया के शिक्षा विभाग ने 'अधिगम तकनीकी योजना' के क्रियान्वयन के कार्य को पूरा करने के लिए 2001 तक का समय सुनिश्चित किया है। योजना से प्रधानाचार्य, स्टाफ तथा विद्यार्थी व्यावहारिक विशेषताओं से लाभान्वित होंगे जिनके परिणाम इस प्रकार होंगे :

- ❑ कंप्यूटर तक पहुंच होने के कारण वे उसके वर्गीकृत अनुप्रयोगों का अभ्यास कर सकेंगे तथा पाठ्यचर्या परिणाम तथा तुरंत सूचना एवं संचार को अपने विद्यालय के शैक्षिक और प्रचालन संबंधी कार्यक्रमों में प्रयोग करने में सफल होंगे।
- ❑ वे विद्यालय के दिन-प्रतिदिन के कार्यकलापों तथा कार्यक्रमों में अधिगम तकनीकों के नियमित, सक्षम तथा विवेचक प्रयोगकर्ता बन जाएंगे।
- ❑ तकनीकी साधनों की विविधता के प्रयोग में कार्यकुशलता प्राप्त कर लेंगे।
- ❑ अधिगम तकनीकों के प्रयोग में नेतृत्व तथा नवीनता दिखाएंगे।

विक्टोरिया में स्मार्ट स्कूलों को 'नेविगेटर स्कूल्स'

कहा जाता है। ग्लेन वेवर्ली सेकण्डरी स्कूल एक ऐसा ही नेविगेटर स्कूल है। यह मैलबॉर्न शहर के निकट पूर्वी ओर स्थित है। स्मार्ट सेकंडरी स्कूल विद्यालय को चलाने के लिए उदाहरण के तौर पर ग्लेन वेवर्ली सेकंडरी कॉलेज की संक्षिप्त रूपरेखा नीचे दी जा रही है :

ग्लेन वेवर्ली सेकण्डरी कॉलेज

इस माध्यमिक विद्यालय में कक्षा 7 से 12 तक शिक्षा प्रदान की जाती है। इस माध्यमिक विद्यालय में :

- ❑ 7 मिलियन डॉलर के विश्व स्तरीय विज्ञान और प्रौद्योगिकी केंद्र सहित 187 सीटों वाला व्याख्यान भवन है जो नवीनतम दृश्य-श्रव्य और संचार सुविधाओं से सुसज्जित है। साथ ही केड (कंप्यूटर एडेड डिज़ाइन) कार्यक्रमों के प्रसारण के योग्य डिज़ाइन कक्ष तथा विज्ञान प्रयोगशाला के कमरे व कंप्यूटर पर आधारित अधिगम तकनीकों की अपार क्षमता में सहायक तथा सुयोग्य कंप्यूटर नेटवर्क वाले कक्षा कक्ष भी हैं। पूरे विद्यालय में इंटरनेट तथा पुस्तकालय संबंधी सुविधाओं के नेटवर्क सहित 400 कंप्यूटर हैं।
- ❑ कक्षा में विद्यार्थियों द्वारा प्रयोग किए जाने वाले तथा सभी 120 स्टाफ सदस्यों द्वारा प्रयोग किए जाने वाले नोटबुक कंप्यूटर हैं।
- ❑ एक विस्तृत पुस्तकालय है।
- ❑ एक मिलियन डॉलर का एक वरिष्ठ विद्यार्थी केंद्र है।
- ❑ एक पूर्ण विकसित कला स्कंध है।
- ❑ एक नाटक केंद्र है।
- ❑ एक संगीत केंद्र है।
- ❑ एक बड़ा सभा भवन है।
- ❑ एक व्यायामशाला, अण्डवक्र तथा एक कृत्रिम घास का बहुद्देशीय क्रीड़ा स्थल है।

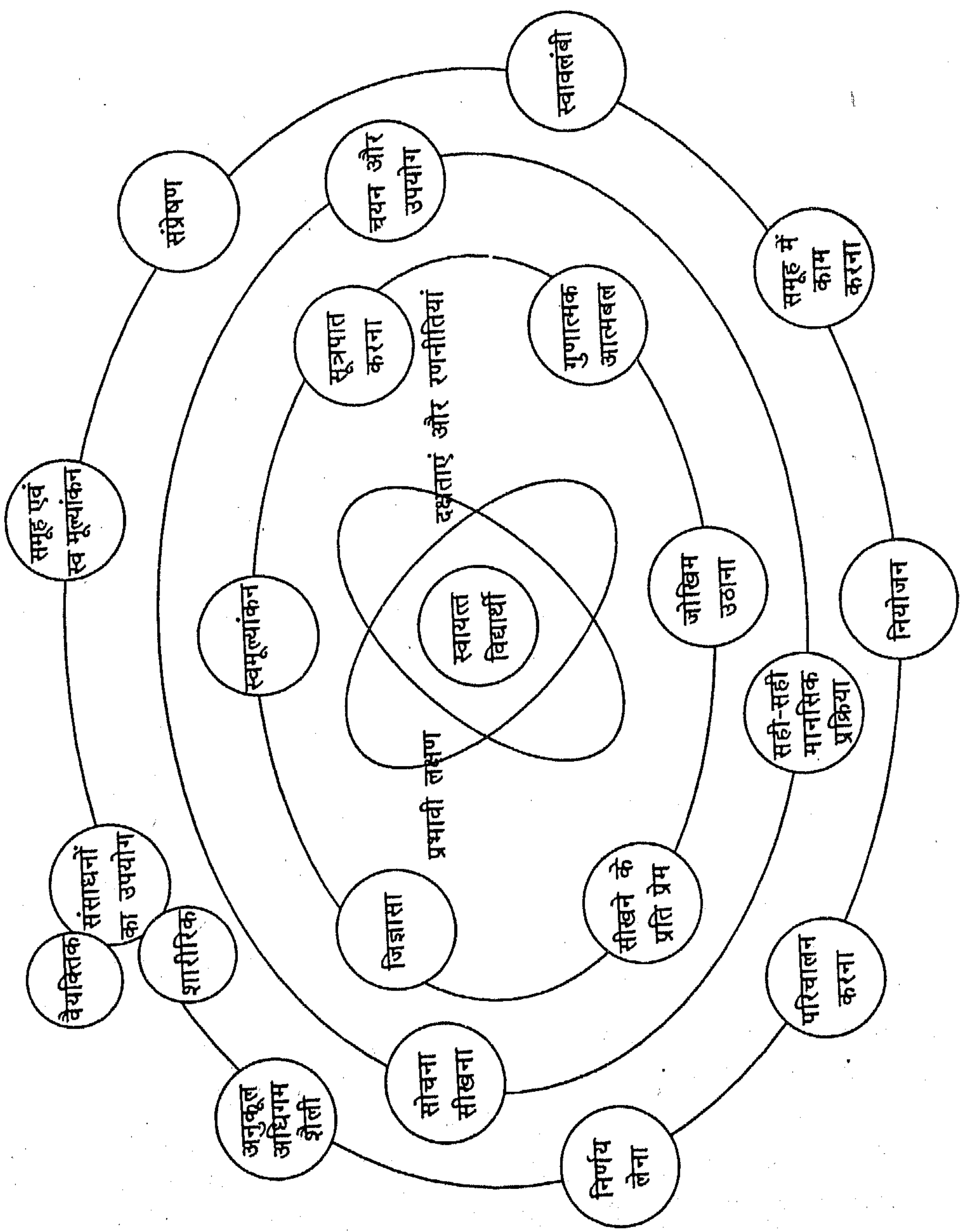
इस विद्यालय में 40 से भी अधिक देशों के लगभग 1500 विद्यार्थी हैं।

इस विद्यालय का शैक्षिक कार्यक्रम इस प्रकार से बनाया गया है जिससे व्यक्ति के संपूर्ण व्यक्तित्व के विकास में सहायता मिले, व्यक्ति में सकारात्मक आत्म छवि बने, वह उत्कृष्टता प्राप्त करने के लिए प्रयास करे और दूसरों के अधिकारों का सम्मान करे। उसका अंतर्राष्ट्रीय परिप्रेक्ष्य हो और वह एक विश्व नागरिक के रूप में सफलतापूर्वक अपनी कार्यकुशलता को प्रदर्शित कर सके। यह विद्यालय प्रत्येक विद्यार्थी को एक स्वायत्त विद्यार्थी के रूप में विकसित होने में सहायता प्रदान करता है। इस विद्यालय द्वारा परिभाषित एक स्वायत्त विद्यार्थी की संकल्पना को निम्नलिखित रेखाचित्र द्वारा प्रदर्शित किया गया है :

क्या भारत में स्मार्ट स्कूलों की आवश्यकता है?

विभिन्न देशों की स्मार्ट स्कूल परियोजनाओं ने यह अनिवार्य बना दिया कि यदि हमें अपने बच्चों को उच्च प्रदत्त ज्ञान कार्य के लिए तथा एक अधिगम समाज में योगदान देने के लिए शिक्षा देनी है तो हमें उन्हें देश के वर्तमान बेहतरीन

एक स्वायत्त विद्यार्थी



पब्लिक स्कूलों तक में दी जा रही शिक्षण अधिगम पद्धति से भिन्न विद्यालयी शिक्षा प्रदान करनी होगी। शिक्षा बोर्डों द्वारा कुल मिलाकर कंप्यूटर विज्ञान के पाठ्यक्रमों के अध्यापन और शिक्षण तथा सूचना तकनीक के साधनों पर बल दिया जाता है। संभवतः आजकल कुछ ही विद्यालय, अधिगम संवर्धन के लिए एक प्रक्रिया के रूप में सूचना तकनीक का प्रयोग कर रहे हैं। इसलिए विद्यालयों के पुनः प्रबोधन की आवश्यकता है ताकि बच्चों को जीवनपर्यंत विद्यार्थी बनाने के लिए तैयार करने हेतु समुचित अध्यापन पद्धति अपनाई जा सके तथा उन्हें भावी सूचना युग में आजीविका के लिए आवश्यक कौशल पूर्ण रूप से प्रदान किए जा सकें। यह जानकर संतोष हुआ कि सरकार ने सूचना तकनीक के लिए बनाई गई राष्ट्रीय कार्य योजना में ज्ञान प्रक्रिया (ऑपरेशनल नॉलेज इन दि नेशनल एक्शन प्लान फॉर इंफोरमेशन टेक्नोलजि) के घटक के अंतर्गत स्मार्ट स्कूल खोलने की इच्छा व्यक्त की है।

अर्थव्यवस्था की विश्व व्यापकता के साथ-साथ हमारे बच्चों को ऐसे कौशलों की आवश्यकता है जैसे विश्व के अन्य विकसित देशों के विद्यालयों के बच्चे प्राप्त कर रहे हैं। हमें अपने स्मार्ट स्कूलों की रूपरेखा तैयार करने के लिए नए सिरे से शुरुआत करने की बजाय अन्य देशों के स्मार्ट स्कूलों के अनुभवों का विश्लेषण करना होगा।

भारत में शिक्षा को सूचना समाज के संगत बनाने के लिए कुछ विचार पहले से ही उपलब्ध हैं।[3, 4] यह सराहनीय है कि सूचना तकनीक और संचार तकनीक में उन्नति के साथ-साथ हार्डवेयर तथा सॉफ्टवेयर में बार-बार परिवर्धन हुए हैं। भारत में भी स्मार्ट स्कूलों को सूचना तकनीक में विश्वव्यापी विकास के साथ आगे बढ़ाना होगा। इसके लिए हमें उस मानसिकता में आमूल परिवर्तन लाना होगा जिस मानसिकता के अनुसार एक बार खरीद ली गई मशीन से तकनीक पुरानी हो जाने के बावजूद हम चिपके रहना चाहते हैं। कंप्यूटर साक्षरता के अध्यापन के लिए लगभग 3000 विद्यालयों द्वारा आज तक प्रयोग में लाए जा रहे चौदह वर्ष पुराने बी.बी.सी. माइक्रोकंप्यूटर कालदोषयुक्त हैं और ये व्यर्थ का प्रयास लगते हैं।[5] स्मार्ट स्कूलों में सूचना तकनीक के साधनों को लगातार अद्यतन करने की ज़रूरत है।

एक स्मार्ट स्कूल में प्रत्येक विद्यार्थी को प्रारंभिक स्तर पर सूचना तकनीक का जानकार बनाया जाएगा। प्रारंभ में विद्यालय द्वारा प्रति चार बच्चों के लिए एक कंप्यूटर उपलब्ध करवाया जा सकता है। सभी कंप्यूटर इंट्रानेट और इंटरनेट से जुड़े होंगे। ये इंटरनेट तत्काल ही शीघ्र-वीडियो-कांफ्रेंसिंग सुविधा उपलब्ध कराने में सक्षम होंगे। पुस्तकालय और इंटरनेट से प्राप्त सूचनाओं के प्रक्रियन के द्वारा विद्यार्थी शिक्षा प्राप्त करेंगे। पारंपरिक विद्यालयी विषयों का अधिगम तथा शिक्षण चलता रहेगा किंतु अधिगम का मुख्य दायित्व विद्यार्थियों पर होगा जो अपने अध्यापकों के मार्गदर्शन में व्यक्तिगत और सामूहिक दोनों प्रकार की परियोजनाओं पर कार्य करेंगे। यह सिद्ध हो चुका है कि अधिगम की यह विधि विद्यार्थी में स्वाभिमान तथा आत्मविश्वास उत्पन्न करती है।

स्मार्ट स्कूल की स्थापना में सबसे बड़ी चुनौती, उन अध्यापकों के चयन की होगी जो विद्यार्थियों के अधिगम में मार्गदर्शक की भूमिका निभा सकें। स्मार्ट स्कूलों के अध्यापकों को ऐसी शिक्षण विधि को अपनाना होगा जिसमें विद्यालयी विषयों के अधिगम के लिए सूचना तकनीक को एक साधन के रूप में प्रयुक्त किया जा सके। साथ ही वर्तमान में अध्यापक शिक्षा कार्यक्रमों के माध्यम से प्राप्त पारंपरिक शिक्षण विधि के साथ सूचना तकनीक को मिलाने की भूल से बचना होगा।

स्मार्ट स्कूल परियोजना एक अच्छा विद्यालय गठित करने से कई गुणा अधिक महंगी पड़ेगी। नवीनतम कंप्यूटर खरीदने के लिए प्रारंभिक स्तर पर भारी पूंजी निवेश करना होगा और उच्च गति पर इंटरनेट पहुंच प्राप्त करने, हार्डवेयर और सॉफ्टवेयर के अनुरक्षण और इन्हें नवीनतम बनाए रखने के लिए लगातार होने वाले खर्च के लिए धन की आवश्यकता होगी। यदि हम अपने बच्चों को उस ढंग और स्तर की शिक्षा देना चाहते हैं जैसी कि सिंगापुर, मलेशिया और आस्ट्रेलिया के बच्चे प्राप्त कर रहे हैं, तो स्मार्ट स्कूल स्थापित करने के लिए राज्य द्वारा अथवा उद्यमियों द्वारा या दोनों द्वारा संसाधन उपलब्ध करवाने होंगे। स्मार्ट स्कूलों की शुरुआत आज एक चुनौती है। ❑

संदर्भ

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बौद्धिक उद्वेलन

जमनालाल बायती

पूर्व प्राचार्य, आई.ए.एस.ई.
बी 186, डा. राधाकृष्णन नगर
भीलवाड़ा, राजस्थान

विचारों की अभिव्यक्ति तथा प्रवाह के लिए बौद्धिक उद्वेलन एक उत्साहवर्द्धक एवं उपयोगी उपागम है। इस उपागम में समस्या या प्रकरण या विषय पर दल के सहभागी साथ बैठते हैं, एक दूसरे से विचार-विमर्श करते हैं, उन्हें उत्साह मिलता है, उनकी समझ-बूझ बढ़ती है तथा एक दूसरे को सही रूप में समझने का अवसर मिलता है। अपनी विशिष्ट कार्य पद्धति से यह उपागम छोटे-बड़े सभी दलों में उपयोगी एवं प्रभावी पाया गया है तथा बुद्धिजीवियों में इस पद्धति ने अपनी पहचान बनाई है। इस उपागम में विषय या समस्या चयन सहित अनुवर्ती कार्यों में पूरी-पूरी सावधानी बरतने की अपेक्षा की जाती है।

अंग्रेज़ी के Brain Storming शब्दों के लिए हिंदी के शब्द बौद्धिक या मस्तिष्कीय या मानसिक उद्वेलन या झंझावात या उत्तेजना प्रयोग किए जा सकते हैं। इस रचना में बौद्धिक उद्वेलन शब्दों का प्रयोग किया गया है। व्यवहार में देखा जाता है कि एक व्यक्ति की सम्मति या विचार या राय की अपेक्षा अधिक व्यक्तियों द्वारा अभिव्यक्त राय या सम्मति या विचार नवीनता, अनोखापन, भिन्नता तथा अपनापन लिए होते हैं। इस राय या विचार की दूसरों से भिन्नता ही उसका व्यक्तित्व होता है। आदमी प्रायः एक दूसरे के नवीन विचारों को महत्व नहीं देते या उन्हें सामान्य ही समझते हैं, पर सामूहिक चिंतन तकनीक आज ब्रेन स्टोर्मिंग या बौद्धिक उद्वेलन के शीर्षक से महत्व पाती जा रही है।

मस्तिष्क में विचारों के आने के साथ ही समस्या समाधान के लिए दल की सहायता हो जाती है, राह निकल आती है। उद्देश्य तो यह है कि एक ऐसा वातावरण निर्मित किया जाए जिसमें अधिकाधिक विचार प्रस्तुत हों। ऐसा विश्वास किया जाना चाहिए कि इन भिन्न-भिन्न तथा नवीन विचारों से पूर्व असंबद्ध वस्तुओं या स्थितियों के बारे में नए विचारों का युग्म या समूह या सम्मिश्रण प्राप्त हो सकता है। इस विवेचन के बाद बौद्धिक उद्वेलन की परिभाषा यों दी जा सकती है—बौद्धिक उद्वेलन एक ऐसी दलीय सामूहिक गतिविधि है जिसमें सम्भागी या अनिवार्यतः सदस्य मौखिक रूप से राय व्यक्त करते हैं या अपना विचार प्रस्तुत करते हैं तथा उस राय या विचार पर वाद-विवाद या विचार-विमर्श, आलोचना या

विश्लेषण नहीं किया जाता। विचारों पर भविष्य में आगे काम करने की दृष्टि से उन्हें लिपिबद्ध कर लिया जाता है।

कई व्यक्तियों द्वारा काम में लाई जाने वाली ब्रेन स्टोर्मिंग या बौद्धिक उद्वेलन तकनीक सृजनात्मक प्रक्रिया को अग्रसर करने के लिए प्रसिद्ध रही है। बौद्धिक उद्वेलन का उद्देश्य विचारों की जांच पड़ताल करना रहा है जिसका मूल्यांकन किया जा सकता है। तभी वह सृजनात्मक उपचार के रूप में काम में लाई जा सकती है। बौद्धिक उद्वेलन का आशय ही यह है कि किसी समस्या के हल के लिए विभिन्न विकल्पों के माध्यम से विचारों की आंधी या तूफान प्रस्तुत हो। किसी भी समस्या के समाधान या उपचार के लिए साधारणतः विभिन्न विचार मस्तिष्क में उद्वेलित हों, भले ही थोड़े समय के लिए आलोचना या मूल्यांकन को स्थगित करना पड़े। इसी भांति समस्या समाधान के लिए कौशल या तकनीक का विकास किया जा सकता है।

ब्रेन स्टोर्मिंग का विचार प्रारंभ में 1938 में एलेक्स एफ. ऑस्वर्न द्वारा विकसित किया गया। वे रोज़मर्रा के कामों में विचार-विमर्श से संतुष्ट नहीं थे तथा उदासीनता अनुभव करते थे। इसी कारण उन्होंने इसे व्यवस्थित रूप में विचार प्राप्त करने का साधन माना तथा इसे रोज़ के काम-धंधे संबंधी विचार विमर्श का उपयोगी प्रतिस्थापन माना।

इस विवेचन के बाद अब बौद्धिक उद्वेलन के उद्देश्य को यों प्रस्तुत किया जा सकता है :

- सम्भागियों के विचारों की एक दूसरे को जानकारी देना,
- विचारों के विकास का संवर्द्धन करना, प्रोत्साहन देना,
- भविष्य में उपयोग के लिए विचारों की सूची उपलब्ध करवाना,
- किसी समस्या के उपचार के लिए विभिन्न विकल्प सुझाना,
- दल के सोचने की स्थिति, वृत्ति, राय तथा विचारधारा को प्रभावित करना तथा
- समस्या निवारण के लिए विभिन्न विकल्पों पर सकारात्मक दृष्टिकोण विकसित करना।

सृजनात्मकता के संवर्द्धन के लिए बौद्धिक उद्वेलन को दोनों एकाकी तथा सामूहिक तकनीक माना जा सकता है। इसे नए विचारों को जन्म देने के लिए उपयोगी माना जाता है। साहचर्यवाद (एशोसियेशनीज़म) पर आधारित यह एक बौद्धिक उपागम है। यह शब्दों के समान ही सरल तथा वाद-विवाद की परंपरागत शैली से मौलिक रूप से भिन्न है। इस विधि में प्रत्येक विचार की, ज्यों ही सदस्य द्वारा प्रस्तुत किया जाता है, सराहना की जाती है तथा उसे स्वीकार किया जाता है।

अन्य किसी भी विधि की अपेक्षा बौद्धिक उद्वेलन के फलस्वरूप ढेर सारे विचार प्राप्त होते हैं तथा ये सब विधियां, बौद्धिक उद्वेलन को छोड़कर, मूल्यांकन पर अधिक आग्रह करती हैं। बौद्धिक उद्वेलन विधि में सम्भागी विचाराधीन समस्या पर सामान्य रूप से व्यवहार करता है या विचार प्रस्तुत करता है।

दल या किसी एक सम्भागी को संभावित सृजनात्मक उपचार या हल प्राप्त करने के लिए

विचार करने को उत्तेजित किया जाता है। सामान्यतया समस्याएं नवीन, परंपरागत, अजीब, वास्तविक, आश्चर्यजनक, विनोदपूर्ण, सीधी, सरल, उलझनपूर्ण या अप्राकृतिक होती हैं।

यह कहा जा सकता है कि बौद्धिक उद्वेलन विधि एक प्रकार से विचारों को जन्म देती है जिसमें निर्णय तथा मूल्यांकन को स्थगित करना या टालना भी मिला हुआ है। यह सब इसलिए कि भाग लेने वाले प्रत्येक सदस्य को बोलने, विचार प्रस्तुत करने का अवसर मिल सके। उसे बेढंगे विचार या आलोचना का डर न रहे। विचाराभिव्यक्ति पर किसी प्रकार का कोई बंधन न हो। यह विधि प्रत्येक संगोष्ठी या सम्मेलन में पाए जाने वाले प्रतिबंधों को स्वीकार नहीं करती है, मूल्यांकन के दृढ़ एवं स्पष्ट दिखने वाले प्रभावों पर पुनर्विचार करती है। नए तथा अधिकाधिक विचार प्राप्त करने के लिए बौद्धिक उद्वेलन ही एक मात्र विधि है। किसी भी सदस्य के लिए बिना मूल्यांकन पर विचार किए किसी भी विचार के साथ प्रस्तुत होने के लिए बौद्धिक उद्वेलन एक उपयोगी विधि है। संक्षेप में यह कहा जा सकता है कि बौद्धिक उद्वेलन विधि में विचारों के प्रस्तुतीकरण का ही प्रमुख स्थान है एवं निर्णय तथा मूल्यांकन गौण हो जाते हैं।

कोई भी सजग सदस्य सावधानी से ढेरों विचार प्रस्तुत करने के लिए स्वतंत्र होता है और इन विचारों से ही समस्याओं का सृजनात्मक हल निकल सकता है। एक व्यक्ति या सदस्य के लिए जो अच्छा है, उपयोगी है, यही बात समूह के लिए भी सामान्यतया कही जा सकती है।

बौद्धिक उद्वेलन विधि

बौद्धिक उद्वेलन में भाग लेने वाले सभी सदस्यों को विषय या समस्या या प्रकरण की समय से पूर्व जानकारी दी जानी चाहिए जिससे वे विषय से हटकर विचार प्रस्तुत करने से बच सकें। सम्भागियों से की जाने वाली अपेक्षाएं भी उन्हें बता दी जानी चाहिए। उदाहरणार्थ – सभी विचार केंद्रीय समस्या के इर्द-गिर्द हों, अधिकतम विचार प्रस्तुत किए जाएं, विचार में संशोधन या परिवर्तन सुझाया जा सकता है, इससे दूसरे विचार का जन्म हो सकता है। विचार स्पष्ट तथा कम से कम शब्दों में पूरे अर्थ के साथ प्रस्तुत हों। विचार-विमर्श या आलोचना-प्रत्यालोचना को कोई स्थान न दिया जाए। प्रारंभ में विचारों का प्रवाह धीमा हो सकता है, ऐसी स्थिति में नायक को धैर्य से काम लेना चाहिए, सदस्यों को अपने भाव प्रकट करने के लिए प्रोत्साहन देना चाहिए।

विचार प्राप्ति की दृष्टि से बौद्धिक उद्वेलन विधि में दल के 10-12 सदस्य हो सकते हैं पर अधिक तथा स्वतंत्र विचार-विमर्श तथा पारस्परिक समझ-बूझ विकसित करने के लिए 6 सदस्य ही काफी होते हैं। बौद्धिक उद्वेलन विधि में पुरुष तथा महिलाएं दोनों दल के सदस्य हो सकते हैं। इस प्रकार के दल में प्रायः अधिक प्रतिस्पर्धा तथा उत्तेजना पाई जाती है तथा सरलता से दल का कार्य आगे बढ़ता है, दल के कार्य को गति मिलती है। यदि बौद्धिक उद्वेलन या ब्रेन स्टोर्मिंग विधि को अधिक प्रभावी बनाना है तो समस्या या प्रकरण का ठीक ठीक परिभाषीकरण होना चाहिए।

उसमें ऐसे शब्दों का प्रयोग किया जाए जिनका एक ही अर्थ हो तथा कहने वाले का आशय ही सही रूप में सुनने वाला भी समझे। इसलिए शब्दों का चयन बड़ी सावधानी से करना चाहिए, द्विअर्थी शब्दों से बचना नितांत ज़रूरी है। प्रायः यह कहा जाता है कि समस्या का हल खोजने के लिए निर्णय की अपेक्षा विचार प्राप्ति अधिक महत्वपूर्ण है।

एक निश्चित समय में जो भी विचार आपके समाने आएं, उन्हें सूचीबद्ध कर लीजिए। इस कार्य के लिए 30 से 40 मिनट पर्याप्त माने जाते हैं। रुचिप्रद विषय होने पर बहुत कम अवसरों पर इस पकार का सत्र घंटे भर भी चल सकता है। विचारों को लिखने के लिए एक सहायक या रिकार्डर बना लीजिए। यदि सम्भागियों की संख्या अधिक है तो सहायक बढ़ाए जा सकते हैं। इस बात पर आप कोई विचार न कीजिए कि विचार अव्यावहारिक है या उस पर कोई कार्य आगे नहीं बढ़ाया जा सकता। आप केवल उन विचारों की सूची तैयार कर लीजिए। विचारों की गुणवत्ता, उनका मूल्यांकन, उनका स्तर या उनकी आलोचना को लेकर कोई भी सदस्य भिन्न राय रख सकता है। ज़रूरी नहीं है कि सब सदस्य एक ही राय के हों। विचार प्रस्तुत करने, सुझाव देने का समय खत्म होने के बाद भी कोई कुछ कहना चाहे तो पूछ लीजिए। यदि आप ऐसा नहीं करते हैं तो इस बात की पूरी-पूरी संभावना है कि कुछ ऐसे विचार जिन्हें आप अपरिपक्व मान रहे हैं वे किसी समय उपयोगी सिद्ध हो सकते हैं। विचार प्रस्तुत करने का समय खत्म होने पर सूचीबद्ध विचारों को पढ़िए, दूसरी बार पढ़िए। आप पाएंगे कि कुछ विचारों में समानता है। ऐसे विचारों को एक साथ एक जगह रख लीजिए। यदि आवश्यक हो तो उनकी भाषा में सुधार कर लीजिए। अब ये विचार दल के लिए अधिक उपयोगी हो सकते हैं। अब आप उन विचारों को हटा भी सकते हैं या विचार क्षेत्र से बाहर कर सकते हैं जिन्हें आप असंबद्ध, अनुपयोगी पाते हैं या जिनकी भाषा में सुधार नहीं किया जा सकता। इस कार्य में पूरी सावधानी बरतिए।

जिस समस्या का चयन किया जाए, वह ऐसी हो कि उसके हल के लिए कई विकल्प या संभव उपचार हो सकें। दल नायक सदस्यों के विचार तथा सुझाव आमंत्रित करता है। सदस्य जैसा बोलते हैं, सुझाव देते हैं, एक विचार से संबंधित दूसरे विचार का जन्म होता है। ऐसे विचार अचानक प्राप्त होते हैं तथा बौद्धिक उद्वेलन विधि में महत्त्वपूर्ण भूमिका निभाते हैं। प्रायः त्रुटियों तथा असंबद्धताओं से बचा जाता है।

सामान्यतया बौद्धिक उद्वेलन विधि में सम्भागी बोलते हैं, विचार प्रकट करते हैं, सुझाव देते हैं पर साथ ही वे दूसरे सम्भागियों के बोलते समय बाधा नहीं पहुंचाते हैं। वे उनकी बात भी धैर्य से सुनते हैं तथा गुणावगुण की दृष्टि से सोचते हैं। जब तारतम्य जोड़ने की बात हो तो प्रत्येक सम्भागी अपनी बारी आने की प्रतीक्षा करता है। बारी आने पर ही सुझाव देता है। जब एक सदस्य ऐसा कर लेता है तो बारी वाला दूसरा सदस्य अपना विचार या सुझाव प्रस्तुत करता है। इस प्रकार प्रत्येक सम्भागी को अपनी बात प्रस्तुत

करने का अवसर मिलता है। विचारों या सुझावों का जब एक चक्र पूरा हो जाता है तो दूसरा चक्र आरंभ किया जाता है। यदि कोई सम्भागी न बोलना चाहे या उसके पास कोई सुझाव नहीं है तो वह शांत रहता है। पर यह भी उसे अपनी बारी आने पर ही बताना चाहिए। यदि नायक यह महसूस करे कि सम्भागियों को सोचने-विचारने के लिए और समय दिया जाना चाहिए तो उनकी राय लेकर वह ऐसा कर सकता है।

बौद्धिक उद्वेलन विधि में कोई भी एक सम्भागी पूरे समय ही बोलता नहीं रह सकता अर्थात पूरे समय किसी एक सम्भागी को ही बोलने का अधिकार नहीं होता। प्रत्येक सम्भागी को अपनी बारी का उपयोग करना ही चाहिए। कई नए विचारों का जन्म हो सकता है तथा कई भिन्न विचार भी, सामने आते हैं। इसके सिवाय बौद्धिक उद्वेलन प्रक्रिया के चलते समय कोई आलोचना नहीं की जाएगी। प्रायः असंगत विचार या असंबद्ध सुझाव भी आते हैं। उनका भी स्वागत है। इन्हें भी प्रोत्साहन दिया जाता है। सम्भव है, इनसे जुड़ा कोई उपयोगी विचार या सुझाव भी कोई सम्भागी प्रस्तुत कर सकें। यह भी संभव है कि इस विचार-विमर्श में कोई व्यावहारिक विचार दिमाग में आ जाए। प्रायः प्रारंभ में सभी विचारों या सुझावों का स्वागत कीजिए और गुणवत्ता की अपेक्षा संख्या पर अपना ध्यान केंद्रित कीजिए। अंत में सहयोगी सम्भागियों को अवसर दीजिए कि वे नया विचार या सुझाव प्रस्तुत कर सकें। इन्हीं सुझावों से नया विचार जन्म लेता है। विचार प्रस्तुत करने का समय समाप्त होते समय दल से नायक कहता है कि आलोचना पर प्रतिबंध समाप्त हो गया है तथा तब वह अन्य सम्भागियों को अपने विचारों का मूल्यांकन करने के लिए निर्देशित करता है तथा प्राप्त सुझावों एवं विचारों में से श्रेष्ठ का चयन करवाता है।

जब कभी अनुवर्ती कार्य की योजना बने तो रिकार्ड किए गए विचारों का उपयोग कीजिए। इन विचारों की भाषा में यहां-वहां न्यूनाधिक परिवर्तन किया जा सकता है। इस कार्य में नीचे लिखी बातों पर ध्यान दिया जाना चाहिए :

- ❑ प्राप्त विचारों का विश्लेषण, आलोचना एवं प्रत्यालोचना।
- ❑ आलोचना-प्रत्यालोचना के बाद प्राथमिकताएं निश्चित करना, संशोधन सुझाना एवं विचारों का संयुक्तीकरण आदि।
- ❑ विचारों का संपादन, उनमें संशोधन तथा सुधार हेतु सुझाव मांगना।
- ❑ कार्यों को क्लब करना या मिलाना, चुनौतियों तथा कार्य विधि में सुधार की दृष्टि से सुझाव आमंत्रित करना।

बौद्धिक उद्वेलन तकनीक

बौद्धिक उद्वेलन तकनीक के दो मुख्य सिद्धांत हैं : प्रथम, निर्णय का स्थगन या टालना तथा द्वितीय संख्या के बाद ही गुणवत्ता पर आग्रह।

प्रथम सिद्धांत का आग्रह रहता है कि वैचारिक प्रक्रिया के लिए विवेक सम्मत दिमाग के साथ-साथ सृजनात्मक मस्तिष्क भी ज़रूरी है। विवेक सम्मत मस्तिष्क विचारों या सुझावों का विश्लेषण करता

है, तुलना करता है, चयन करता है तथा मूल्यांकन करता है जबकि सृजनात्मक मस्तिष्क कल्पना करता है, आगे के लिए सोचता है तथा बिना किसी संदेह के नए विचारों को जन्म देता है।

व्यवहार में विवेकी मस्तिष्क सृजनात्मक मस्तिष्क पर प्रतिबंध लगाता है। पर इन बंधनों को हटाया जाना चाहिए जिससे हर समय नए-नए विचार प्रस्तुत होते रहें। इन बंधनों को हटाने के लिए बौद्धिक उद्वेलन का पहला सिद्धांत निर्णय लेने पर विचार किया जाना चाहिए तथा उसका अनुकरण किया जाना चाहिए। कोई भी सम्भागी अपने विचार बिना उनका महत्व या व्यावहारिकता का ध्यान रखे बता सकता है या सुझाव (लिखकर भी) दे सकता है।

संख्या की अपेक्षा गुणवत्ता के विकास के संबंध में यह ज़रूरी है कि मौलिक विचार प्राप्त करना है तो इन परंपरागत विचारों को भी स्वीकार किया जाए। तारतम्यता की प्रक्रिया को सामान्य बौद्धिक उद्वेलन की विधि में महत्व दिया ही जाना चाहिए। शुरू-शुरू में या प्रारंभिक स्थिति में गुणवत्ता या श्रेष्ठता की अपेक्षा नहीं की जा सकती पर प्रतिफलों की अधिक मात्रा का प्रयत्न तो किया ही जाना चाहिए।

बौद्धिक उद्वेलन के नियम

बौद्धिक उद्वेलन के सिद्धांतों की जानकारी प्राप्त कर कोई भी जिज्ञासु इसके नियमों का ज्ञान अवश्य ही प्राप्त करना चाहेगा। इन नियमों की रचना यों की जा सकती है। यथा प्रारंभ में विचारों या सुझावों की आलोचना को कोई स्थान नहीं दिया जाए सहज विचाराभिव्यक्ति का सम्मान कीजिए, उसे मान्यता दीजिए। प्रारंभ में विचारों की अधिकतम संख्या पर आग्रह रहना चाहिए तथा अंतिम विचारों के समन्वय या संयुक्तीकरण तथा सुधार की संभावना खोजिए।

जैसा कि बताया गया है बौद्धिक उद्वेलन में सजगता एवं सावधानी के साथ किए गए प्रयास सम्मिलित हैं जिसे सृजनात्मक प्रक्रिया कहा जा सकता है। दल में कुछ ऐसे सम्भागियों को सम्मिलित करना चाहिए जो स्वयं पहल करने के, विचार प्रस्तुत करने के एवं सुझाव देने के लिए उद्यत रहते हों। इससे कार्य को आगे बढ़ाने में दल को बड़ी मदद मिलती है। यदि कोई एक सम्भागी दल पर प्रभुत्व जमा लेता है या विचार प्रस्तुत करने के लिए दल पर एकाधिकार कर लेता है तो उन्हें दल के सामान्य हित में ऐसा न करने का संकेत करना चाहिए। सबको अपनी बात कहने का निर्विवाद रूप से अवसर मिलना ही चाहिए।

बौद्धिक उद्वेलन विधि की सावधानियां

बौद्धिक उद्वेलन विधि के क्रियान्वयन में कुछ गलतियां या कमियां हो सकती हैं। सजग रहकर उनसे बचा जा सकता है। यदि इन सावधानियों पर ध्यान दिया जा सके तो बौद्धिक उद्वेलन को अधिक प्रभावी एवं उपयोगी बनाया जा सकता है।

बौद्धिक उद्वेलन का तब तक आयोजन नहीं करना चाहिए जब तक सम्भागियों द्वारा प्रस्तुत

विचारों या सुझावों के अनुसार काम करने का तथा हल ढूंढने का मन न हो। इसलिए ज़रूरी है कि नायक सहित सम्भागियों की विषय, प्रकरण या समस्या में रुचि हो। ऐसा करने पर ही सम्भागियों को संतोष होगा कि उनके सुझावों या विचारों को महत्व दिया जा रहा है। जब किसी समस्या के प्रत्यक्षतः एक दो ही हल दिख रहे हों तो बौद्धिक उद्वेलन का आयोजन व्यर्थ होगा। यहां यह भी जानना महत्वपूर्ण है कि सत्र के दौरान प्राप्त प्रत्येक विचार या सुझाव पर कार्य होगा ही – ऐसा संभव नहीं है तथा न ही व्यावहारिक। इसीलिए आलोचनात्मक विश्लेषण महत्वपूर्ण है। जब किसी समस्या या विषय पर उसके विशेषज्ञ या ख्याति प्राप्त जानकार से परामर्श किया जा रहा हो तब भी बौद्धिक उद्वेलन का आयोजन निरर्थक हो सकता है। ऐसा विश्वास करने के लिए पर्याप्त आधार हैं :

- ❑ बौद्धिक उद्वेलन कार्यक्रम को किसी नायक से संरक्षण या प्रोत्साहन न मिलना – इस स्थिति में सम्भागियों का उदासीन या निरुत्साही होना स्वाभाविक है।
- ❑ बौद्धिक उद्वेलन की बिना आधार या समय पूर्व शेखी बघारना तथा सम्भागियों से उनकी योग्यताओं से बाहर अधिक उच्च विचार या सुझाव की आशा करना।
- ❑ दल द्वारा वांछित तरीके से निष्कर्ष निरूपण में असफलता।
- ❑ बौद्धिक उद्वेलन विधि से अपरिचित सम्भागियों को बिना संशोधन, समन्वय तथा मूल रूप में ही विचारों की सूची प्राप्त कराना–अच्छा यह होगा कि इस सूची को जब तक सम्भव हो, गोपनीय रखा जाए।
- ❑ इस बात के लिए आश्वस्त न होना कि अगला क्या कदम लिया जाने वाला है।
- ❑ यदि कभी सम्भागी विषय से परे हटकर विचार प्रस्तुत करे तो नायक को सावधानी से विषय की याद दिलाते हुए सम्भागियों को विषय या समस्या या प्रकरण पर लाना चाहिए। ध्यान रखिए – उनकी वैयक्तिकता को ठेस न पहुंचे।

बौद्धिक उद्वेलन की सफलता के लिए स्थितियां

कार्यक्रम प्रभारी या दल नायक को सभी सम्भागियों के बीच समरसतापूर्ण वातावरण बनाना चाहिए। सम्भागियों को मनौवैज्ञानिक रूप से आश्वस्त कीजिए, कि उनके विचारों से उनकी कोई हानि नहीं होगी, उन्हें विश्वास दिलाइए कि सभी विचार महत्वपूर्ण हैं तथा दल के सुयश या हित में उनका स्वागत है। परंपरागत तरीके की सोच से हटाकर सम्भागियों को समस्याओं पर नई तथा भिन्न दृष्टि से देखने को तैयार कीजिए। आप उनका उत्साहवर्द्धन कीजिए। उनके विचारों को मान्यता दीजिए, उन्हें स्वीकार कीजिए, उन्हें वैयक्तिक स्तर से ऊपर लाकर समूह के रूप में सोचने को तैयार कीजिए, उनकी कल्पनाओं की स्वतंत्र अभिव्यक्ति में बाधा न पहुंचे–ऐसी कार्य विधि चुनिए या खोजिए। नायक को अपने दल के सम्भागियों को प्रोत्साहन देना चाहिए कि

सम्भागी आपस में वैचारिक मंथन करें, एक दूसरे के विचारों को जानें, परखें। इससे सम्भागियों में विश्वास विकसित होगा तथा बड़ी समस्याओं को हल करने की तकनीक जानेंगे। वे इस कला में पारंगत होंगे। जब वे स्वयं समस्याएं हल करेंगे तो अनुभव से उनका विश्वास दृढ़ होगा। समस्याओं को हल करने का अनुभव पाकर वे सहज ही समस्याओं को चुनौती देंगे। वे अपने अनुभवों को जितना चाहें विस्तार दे सकते हैं। ऐसे सम्भागियों के लिए संभव है बौद्धिक उद्वेलन से वे अपने पुराने विचारों से मुक्ति पा लें अर्थात यह विधि उन्हें अपने पुराने विचारों को त्यागने के लिए क्रमशः तैयार करेंगी ऐसा विश्वास किया जाना चाहिए।

बौद्धिक उद्वेलन विधि का उपयोग

यह सचेत होकर ध्यान रखना चाहिए कि सामूहिक बौद्धिक उद्वेलन विधि नीचे बताई दो स्थितियों में बहुत अधिक प्रभावी नहीं होगी, उद्देश्य प्राप्ति में मददगार नहीं होगी, उसकी पूरक की भूमिका भी नहीं रहेगी :

- ❑ वैयक्तिक विचारधारा के विकास के उपागम
- ❑ परंपरागत सभा सम्मेलनों तथा संगोष्ठियों का आयोजन।

बौद्धिक उद्वेलन से ८० प्रतिशत अधिक विचार प्रस्तुत होते हैं। इनमें से अधिकांश एक दूसरे के लिए नवीन होते हैं। बौद्धिक उद्वेलन का विज्ञापन, शिक्षा प्रचार तथा व्यापार के क्षेत्रों में महत्वपूर्ण स्थान है। इस विधि से नए विचार तथा मौलिक प्रतिफल प्राप्त किए जा सकते हैं और इन्हीं से आज की समस्याओं का हल खोजा जा सकता है।

बौद्धिक उद्वेलन का महत्व नैतिकता एवं मनोबल में देखा जा सकता है। पर्यवेक्षण संबंधी समस्याओं के प्रति दृष्टिकोण में सुधार या परिवर्तन लाकर पर्यवेक्षक अधिकारी तथा पर्यवेक्षित कार्मिक या अधिकारी के मध्य मधुर संबंध विकसित किए जा सकते हैं – एक दूसरे को सही रूप में समझने की तकनीक या समझ-बूझ विकसित की जा सकती है। ऐसे विचार प्रस्तुत होते हैं या सामने आते हैं जो सृजनात्मक हैं, उपयुक्त हैं, संतोष देते हैं, अच्छे हैं, सराहनीय हैं, व्यावहारिक हैं तथा इन सबसे अधिक पारस्परिक मधुर संबंधों के विकास में प्रभावी एवं निर्णायक भूमिका निभाते हैं। बौद्धिक उद्वेलन से प्राप्त विचार उपयोगी, प्रभावी तथा व्यावहारिक हैं तथा स्पष्टेता दर्शाते हैं। इस प्रकार ऊपर के विवेचन से स्पष्ट है कि बौद्धिक उद्वेलन विधि अध्ययन-अध्यापन के कार्य क्षेत्र में महत्वपूर्ण भूमिका रखती है। ❑

प्राचीन यूनानी शिक्षा-दर्शन और वर्तमान में उसकी प्रासंगिकता

बी.पी. सिंह, प्राचार्य
प्रदीप कुमार पांडेय
प्रवक्ता, ए.पी.एन.पी.जी. कालेज, बस्ती

गीता सिंह
प्रवक्ता
राजा मोहन गर्ल्स पी.जी. कालेज, फैज़ाबाद

वर्तमान परिप्रेक्ष्य में यूनान का प्राचीन शिक्षा-दर्शन भारतीय दर्शन की अनेक बातों से जुड़ा होने के कारण संस्कृति, सभ्यता व शैक्षिक समाज के विकास में महत्वपूर्ण योगदान दे सकता है। यूनानी दार्शनिक जहां एक ओर भारतीय दर्शन के कर्मप्रधान राष्ट्रवाद व निष्काम कर्मयोग में विश्वास करते थे वहीं दूसरी ओर वे परिवर्तनशील राजनीतिक वास्तविकताओं के प्रति भी सजग थे। उनके चिंतन में आदर्शवादी दर्शन की कल्पना ही नहीं संतोषजनक वैज्ञानिक तर्क भी समाविष्ट था। उनमें मानवीय विकास के प्रत्येक पक्ष के प्रति सहज, नैतिक एवं संयमित भाव था, जो आज के परिप्रेक्ष्य में भी अनुकरणीय है।

दर्शन और शिक्षा के क्षेत्र में प्राचीन यूनान ने प्राचीन भारत की तरह व्यापक प्रगति की थी। ईसा के 469 वर्ष पूर्व सुकरात के जन्म लेने के साथ ही यूनान का दर्शन जाग उठा। सुकरात ने अपने जीवन के अंतिम वर्ष (399 ईसा पूर्व) तक दार्शनिक क्षेत्र में समाज को दिशा दी। उसका शिष्य प्लेटो (427 ई.पु.-348 ई.पू.) एक महान काल्पनिक दार्शनिक विचारक था। उन्होंने सर्वप्रथम दार्शनिक विचारों को उदात्त रूप में परिवर्धित करने के लिए शिक्षा को औपचारिक संस्थात्मक स्वरूप प्रदान किया। उसकी शिक्षा संस्था को 'अकादमी' कहा जाता था। इसी 'अकादमी' में एक परम वैज्ञानिक, राजनीतिक व वैचारिक प्रतिमा का धनी व्यक्तित्व अध्ययन करता था जिसे 'अरस्तू' के नाम से जाना जाता है।

अरस्तू ने सुकरात व अपने गुरु प्लेटो के दार्शनिक व कल्पनावादी विचारों को व्यावहारिक यथार्थ व वैज्ञानिक स्वरूप प्रदान करने का अथक प्रयास किया। यूनान का शिक्षा-दर्शन इन तीनों ही महान विचारकों की श्रृंखला के ईद-गिर्द फैला हुआ है। उनके विचार न केवल तत्कालीन सामाजिक परिस्थितियों मे उपयोगी थे अपितु आज के समसामयिक परिवेश में मूलतः लोकतांत्रिक व शैक्षिक वातावरण में आई गिरावट के संदर्भ में भी प्रासंगिक माने जा सकते हैं।

सुकरात धन और सौंदर्य से तो हीन था, किंतु उसमें आत्मविश्वास व साहस कूट-कूट कर भरा था। उसकी बुद्धि विलक्षण थी और वह कर्तव्य के प्रति सदैव सचेष्ट रहता था। इन गुणों का प्रभाव उसके शैक्षिक विचारों में दिखाई देता

है। वह शिक्षा को विकास का आधार मानता है। हज़ारों वर्षों के इतिहास में यह विचार आज भी उतना ही महत्वपूर्ण है जितना कि तत्कालीन समाज में रहा होगा। सुकरात अज्ञानता को बुराई का मूल मानते थे। इसीलिए उन्होंने बुराई को दूर करने के लिए सबसे पहले अज्ञानता को, अशिक्षा को दूर करने का आह्वान किया। विचार-शक्ति से ज्ञान बढ़ता है। सुकरात के अनुसार ज्ञान की उपलब्धि आत्मपरीक्षण द्वारा संभव है। अर्थात हम अपने आप में झांक कर अपनी अच्छाई-बुराई का निर्णय कर सकते हैं।

उसने शिक्षा का उद्देश्य व्यक्ति की चिंतन शक्ति का विकास बताया है। यह मनुष्य को वास्तविक पारखी बनाती है। यह मनुष्य-मनुष्य के मध्य सूक्ष्म भेदों को समझने की शक्ति प्रदान करती है। सुकरात ने शिक्षा को मनुष्य के नैतिक जीवन का मार्गदर्शक बताया है। जो स्व को जानते हैं उन्हें अपनी शक्तियों व दुर्बलताओं के बारे में संदेह नहीं होता। वे अपनी इच्छाओं, आकांक्षाओं का विश्लेषण भली-भांति कर सकते हैं।

सुकरात ने तार्किक शिक्षा पद्धति (Dialectic Method) का समर्थन किया। इसमें प्रश्नोत्तर के माध्यम से सत्य की खोज की जाती है। यह विधि व्याख्यान पद्धति से भिन्न है। प्रश्नोत्तर के माध्यम से तर्क-वितर्क के द्वारा अंतर्क्रिया अधिक होती है। इसके विपरीत आधुनिक व्याख्यान पद्धति में विचार-प्रवाह एक पक्षीय हो जाता है तथा छात्र और शिक्षक में अंतर्क्रिया अपेक्षाकृत कम होती है। सुकराती शिक्षा पद्धति में यह जानने के लिए कि छात्र ने कितना समझा और कितना नहीं, बोधात्मक और धारण के प्रश्न पूछे जाते हैं। यह शिक्षा पद्वति बौद्ध शिक्षा पद्वति से मेल खाती है। Dialectic वह प्रक्रिया है जिसके द्वारा धारणाओं में प्रत्ययों का निर्धारण किया जाता है।

पाठ्यक्रम के निर्धारण में सुकरात ने जीवन के विभिन्न पक्षों के विकास को ध्यान में रखा है। मानव स्वभाव व व्यवहार के अध्ययन के लिए मनोविज्ञान का अध्ययन, मानसिक विकास के लिए काव्य, संगीत व नृत्य का अध्ययन, बौद्धिक विकास के लिए नीतिशास्त्र, आचारशास्त्र, दर्शन व धर्म का अध्ययन तथा शारीरिक विकास के लिए जिमनास्टिक आदि को महत्वपूर्ण माना जाता है।

सुकरात के शिष्य प्लेटो के दार्शनिक विचारों पर उसके गुरु का स्पष्ट प्रभाव था। महात्मा सोलेन जिन्हें प्राचीन एथेंस का महात्मा गांधी कहा जाता है, प्लेटो के पूर्वज थे। वे कहा करते थे कि किसी समाज व देश की उन्नति तभी संभव है जब वहां के नवयुवकों की उन्नति की जाए। प्लेटो इस विचार का समर्थन करते हुए कहता है कि यह कार्य तभी संभव है जब एक सुव्यवस्थित शिक्षा प्रणाली और संगठित पाठ्यक्रम हो। उसने दार्शनिक विचारों का आधार अच्छी शिक्षा पद्धति माना है। अर्थात शिक्षा ही विचार का, नैतिकता का, सद्गुण का स्रोत है।

अपने सिद्धांतों को व्यावहारिक रूप देने के लिए प्लेटो ने एथेंन्स में 386 ई. पू. 'अकादमी' नामक शिक्षण संस्था की स्थापना की, जहां बालक-बालिकाओं को समान रूप से शिक्षा प्रदान की जाती थी। प्लेटो स्त्री-पुरुष के समान अधिकारों

का समर्थक था। वह एक मौलिक एवं वृहद दृष्टिकोण वाला विचारक था। उसकी पुस्तक 'रिपब्लिक' एवं 'लांज' को शिक्षा पर लिखा गया प्रथम ग्रंथ कहा जाता है। उसके अनुसार श्रेष्ठ पुरुषों के गुणों में शिक्षा सर्वप्रथम एवं सर्वश्रेष्ठ गुण है। सुकरात की भांति प्लेटो भी शिक्षा का उद्देश्य सत्य की प्राप्ति करना मानता है। उसने शिक्षा का अंतिम उद्देश्य सद्गुण की प्राप्ति बतलाया है। शिक्षा ऐसे व्यक्तियों को उत्पन्न करती है जो किसी कार्य को सहृदयता व विवेक से करने में समर्थ होते हैं। इस प्रकार शिक्षा से आत्मसंयम का विकास होता है। ज्ञात हो कि आज के समाज में कटुता, विषमता, भ्रष्टाचार व संघर्ष का मूल कारण व्यक्ति में आत्मसंयम की कमी का होना है। इस परिप्रेक्ष्य में प्लेटो द्वारा निर्दिष्ट आत्मसंयम प्रेरित शिक्षा-योजना निश्चित ही अनुकरणीय है।

प्लेटो के अनुसार भावना का संबंध हृदय से है। उसका प्रथम गुण साहस और सहनशीलता है। बिना साहस, धैर्य और सहनशीलता के मनुष्य उन्नति नहीं कर सकता। अतः व्यक्ति में इन गुणों का विकास होना चाहिए। इसके लिए शिक्षा ही उपयुक्त माध्यम है। प्लेटों ने व्यक्ति को सार्थक जीवन जीने के लिए सुकराती शिक्षा योजना की तरह न केवल तर्क व प्रश्नोत्तर प्रणाली का समर्थन किया बल्कि पाठ्यक्रम में भी इस बात पर ध्यान रखा कि जीवन के हर क्षेत्र से संबंधित ज्ञान दिया जा सके। उसने दैनिक जीवन की कुशलता के लिए कृषि, व्यापार, शिक्षा, सौंदर्य-बोध व नैतिकता के विकास के लिए संगीत, नृत्य, काव्य व संगीत-प्रधान शिक्षा पर ज़ोर दिया। उस समय यूनान में संगीत को वैसे ही महत्व दिया जाता था जिस प्रकार यहूदी 'ओल्ड टेस्टामेंट' व ईसाई 'बाइबिल' को महत्व देते हैं। संगीत, साहित्य और कला पर यूनान के लिए ही नहीं, प्राचीन भारतीय संस्कृति में भी मूल रूप में पुराणकाल व स्मृतिकाल में व्यापक ज़ोर दिया गया। साथ ही इसका विकास शिक्षा का मुख्य उद्देश्य माना गया। 'साहित्य संगीत कला विहीन साक्षात पशु पुच्छ विषाण हीन' कहकर इस पर व्यापक ज़ोर दिया गया। संगीत व काव्य को प्लेटो भी संपूर्ण बौद्धिक जीवन का मूल स्रोत मानते हैं।

प्लेटो शिक्षा को जीवन पर्यन्त चलने वाली प्रक्रिया मानता है, अर्थात समय विशेष में या किसी संस्था विशेष में शिक्षा-प्राप्त करना ही पर्याप्त नहीं है अपितु मनुष्य अपने पूरे जीवन काल में सतत रूप से कुछ न कुछ सीखता रहता है। उसके नैतिक संस्कार दिन प्रतिदिन परिवर्धित व परिष्कृत होते रहते हैं।

प्लेटो ने उम्र के अनुसार शिक्षा व्यवस्था को नियोजित किया है। उसने जन्म से 10 वर्ष तक बालक को माता-पिता के प्रभाव से मुक्त रखने की बात कही है। जॉन डी वी व फ्रेबेल तथा रूसो की आधुनिक शिक्षा प्रणालियों में संभवतः प्लेटो की ही प्रेरणा दिखाई देती है क्योंकि इनके द्वारा भी मुक्त्यात्मक अनुशासन का समर्थन किया गया है। इसमें बालक में 'करके सीखने' की प्रवृत्ति का विकास होता है। 6 से 13 वर्ष की आयु में बालक को प्राथमिक शिक्षा के रूप में व्यायाम, खेल व घुड़सवारी की शिक्षा यह संकेत करती है

कि प्लेटो किशोरावस्था प्रारंभ होने के पहले ही बालक को शारीरिक रूप में मज़बूत बनाना चाहता था। यहां प्लेटो के काल्पनिक विचारों में भी वैज्ञानिकता का पुट दिखाई देता है क्योंकि स्वस्थ शरीर में स्वस्थ मस्तिष्क का विकास आसानी से होता है।

13 से 16 वर्ष की उम्र में धर्म व काव्य की शिक्षा थोड़ी अतार्किक अवश्य लगती है क्योंकि धर्म व काव्य जैसे विषय पूर्व किशोरावस्था के लिए उपयुक्त नहीं होते। सैनिक शिक्षा, गणित, ज्योतिष व संगीत के लिए प्लेटो ने 16 से 20 वर्ष की अवस्था स्वीकार की। इसे आधुनिक काल के उच्च शिक्षा मनोवैज्ञानिक भी स्वीकार करते हैं क्योंकि उत्तर किशोरावस्था का यह काल झंझावातों से प्रेरित होने के साथ-साथ स्मरण-शक्ति, व्यक्तित्व-विकास व भविष्य निर्धारण के संदर्भ में बहुत महत्वपूर्ण माना जाता है। आदर्श शासक बनने व दर्शनशास्त्र का गहन अध्ययन करने आदि के लिए प्लेटो ने पूर्ण विकसित आयु 30 वर्ष के उपरांत मानी है। प्राचीन भारतीय विचारकों ने भी इस आयु को गृहस्थ आश्रम का पूर्वकाल स्वीकार किया था जहां व्यक्ति सोचने, विचारने, अपने जीवन के बारे में निर्णय करने, गृहस्थ ज़िम्मेदारियों को निभाने के योग्य हो जाता है।

प्लेटो द्वारा स्त्री-शिक्षा पर ज़ोर दिया जाना तथा बालिकाओं को बालकों के समकक्ष हर प्रकार की शारीरिक व मानसिक शिक्षा प्रदान करने का पक्ष लेना उस युग के लिए बहुत ही महत्वपूर्ण माना जा सकता है। प्लेटो के अनुसार स्त्री पुरुष के समान सभी कार्य करने में क्षमतायुक्त है। उसने अपनी पुस्तक 'रिपब्लिक' में लिखा है: "So far as her nature is concerned the woman is admissible to all pursuits as well as man though in all of them the woman is weaker than man."

उसने इस कथन के साथ-साथ इस बात पर बल दिया है कि बालिकाओं के लिए भी संगीत, नृत्य, सैनिक शिक्षा, जिमनास्टिक, घुड़सवारी, युद्ध आदि की शिक्षा की व्यवस्था होनी चाहिए। विदित हो कि स्त्रियों के प्रति जो मान्यताएं और अधिकार पंद्रहवीं और सोलहवीं शताब्दी में पुनरुत्थान-काल (Renaissance Period) और सुधार युग (Reformation Period) में किसी प्रकार मिल सके उसकी स्पष्ट कल्पना प्लेटो ने लगभग ढाई हज़ार वर्ष पहले ही की थी। उसने 'रिपब्लिक' में एक आदर्श राज्य 'यूटोपिया' की कल्पना करके उसकी स्थिरता के लिए एक आदर्श शिक्षा योजना प्रस्तुत करके वास्तव में आदर्श नागरिक के निर्माण का मार्गदर्शन किया है।

प्लेटो के बाद यूनान के शिक्षादर्शन व राजनीति को व्यावहारिक व वैज्ञानिक स्वरूप प्रदान करने का श्रेय प्लेटो की अकादमी में पढ़ने वाले उसके शिष्य अरस्तू को जाता है। अरस्तू की विलक्षण प्रतिभा को देखते हुए प्लेटो उन्हें 'रीडर' कहते थे। सिकंदर को 'सिकंदर महान' बनाने का कार्य उसके गुरु (शिक्षक) अरस्तू ने ही किया था। सिकंदर ने अरस्तू की प्रशंसा करते हुए लिखा है, "अपने जीवन के लिए मैं अपने पिता का और जीवन किस प्रकार व्यतीत करना चाहिए इसके लिए अरस्तु का ऋणी हूं।"

अरस्तू के शैक्षिक विचार उसकी पुस्तक 'एथिक्स' तथा 'पॉलिटिक्स' में मिलते हैं। 'एथिक्स' में व्यक्तिगत अनुशासन तथा 'पॉलिटिक्स' में समाज के उस सर्वोत्तम रूप की कल्पना की गई है जहां यह अनुशासन संभव हो। अरस्तू व्यक्ति को आत्मसंयम के साथ कार्य करने की सलाह देता है। इस अर्थ में वह व्यक्तिवादी न होकर समाजवादी है। समाज के प्रति उसमें अपार निष्ठा थी। उसके अनुसार "मनुष्य एक सामाजिक प्राणी है। यदि कोई मनुष्य ऐसा है जो समाज में न रहना चाहता हो या उसको समाज की आवश्यकता ही न हो तो वह मनुष्य नहीं हो सकता, वह या तो जंगली जानवर होगा अथवा देवता।" अच्छे नागरिक ही अच्छे समाज का निर्माण करते हैं। अतः अरस्तू के अनुसार शिक्षा ऐसी होनी चाहिए जो व्यक्ति को सद्जीवन प्रदान करे।

अरस्तू ने ऐसी शिक्षा योजना का समर्थन किया है जो व्यक्ति के शारीरिक और मानसिक दोनों के विकास से संबंधित हो। उसके चिरपरिचित वाक्य "Sound body is sound mind" से हर शिक्षित व्यक्ति परिचित है। प्लेटो की तरह अरस्तू ने भी पाठ्यक्रम का निर्धारण उम्र के अनुसार किया है। 7-14 वर्ष की उम्र में चित्रकला, संगीत, व्यायाम व खेलकूद, 14-21 वर्ष की उम्र में गणित, ज्यामिति व खगोलशास्त्र तथा 21 वर्ष के ऊपर की आयु में नीतिशास्त्र, मनोविज्ञान व राजनीति के अध्ययन की बात की है। उसने संगीत को व्यक्तित्व के विकास का आवश्यक अंग माना है। अपनी पुस्तक 'पॉलिटिक्स' में अरस्तू ने लिखा है – "Music has the power of forming the character and could therefore be introduced into the education of the young".

अरस्तू वैज्ञानिक शिक्षा पद्धति का समर्थक है। उसने प्रत्यक्ष अनुभव व रीति द्वारा शिक्षा प्राप्त करने की जिस विधि का प्रतिपादन हज़ारों वर्ष पहले किया आज उसी को आधुनिक शिक्षाशास्त्री भी मान्यता दे रहे हैं। यह आधुनिक वैज्ञानिक पद्धति का मौलिक गुण माना जाता है। अरस्तू ने शिक्षा के क्षेत्र में प्रकृति, विवेक तथा आदत को बहुत महत्व दिया। वह मनुष्य की प्रवृत्ति को चरित्र विकास की ओर ले जाना चाहता था। इसके लिए शिक्षा को योजनाबद्ध होना चाहिए। अतः उसने शिक्षा पर नियंत्रण का दायित्व राज्य को सौंपा। उसका मानना है कि राज्य जीवन के लिए अस्तित्व में आया तथा सद्जीवन के लिए व्याप्त है। अरस्तू ने एक राज वैज्ञानिक होने के नाते अपने शैक्षिक विचारों को राजनीतिक परिधि में ही रखा है। उसने शिक्षा पर राज्य के नियंत्रण की बात की है। अनुशासन को शिक्षा में आवश्यक मानते हुए अरस्तू का कहना है कि योग्य अधिकारी वही बन सकता है जिसमें अनुशासन और नियम-पालन की भावना हो। यथार्थ तो यह है कि अरस्तू शिक्षा द्वारा व्यक्ति को राज्य की सेवा और रक्षा के लिए तैयार करना चाहते थे। अर्थात वे शिक्षा द्वारा राष्ट्र का विकास करना चाहते थे। आज के पथभ्रष्ट राजनीतिक समाज के लिए यह निःसंदेह प्रेरणा का विषय है, क्योंकि आज की राजनीति निजी स्वार्थों के चलते राष्ट्रीयता की भावना से विरत, दिशाहीन हो गई है।

सुकरात, प्लेटो और अरस्तू के विचारों में

सिमटा यूनानी शिक्षा-दर्शन मानव के सर्वांगीण विकास का प्रेरणासूत्र है। इसने जहां एक तरफ व्यक्तिगत मूल्यों, नैतिकता, मानवता, विचार व सद्गुण की प्रेरणा दी है वहीं दूसरी ओर व्यक्ति में राज्य के प्रति त्याग व अद्भुत राष्ट्रीयता की भावना को संजोए हुए है। स्त्री-पुरुष में समता स्थापित करने का आदर्श आज भी विश्व के नूतन क्षितिज पर छाया हुआ है। 'करके सीखने', अनुभव द्वारा सीखने, सरल से कठिन की ओर अधिगम प्रश्नोत्तर प्रणाली द्वारा अंतर्क्रिया तथा शिक्षा में आधुनिक व वैज्ञानिक विश्लेषण का प्रयोग आदि प्राचीन यूनानी शिक्षा प्रणाली की ही देन है। अतः प्राचीन यूनान का शिक्षा दर्शन अपनी अप्रतिम उपलब्धियों के लिए आज भी प्रासंगिक है।

आधुनिक परिप्रेक्ष्य में ग्रीक दर्शन इसलिए भी प्रासंगिक है क्योंकि इसकी बहुत सी बातें भारतीय दर्शन से जुड़ी हुई हैं। इसमें संदेह नहीं कि प्राचीन भारतीय दर्शन का भारतीय संस्कृति एवं सभ्यता के विकास में महत्वपूर्ण योगदान रहा है, बल्कि आधुनिकता की शताब्दियों की सीढ़ी पार करने के बावजूद जन-जन के जीवन पर इसकी अमिट छाप है। भारतीय व पाश्चात्य दोनों दर्शनों के आधार पर यदि ज्ञान मीमांसा का विश्लेषण किया जाए तो दो प्रमुख विचारधाराएं सामने आती हैं। प्रथम विचारधारा ज्ञान को शाश्वत मानती है तथा दूसरी विचारधारा के अनुसार ज्ञान परिवर्तनशील है। वेदांत दर्शन के अनुसार ज्ञान हमारी आत्मा में निहित है तथा शिक्षा द्वारा इसे प्रकाश में लाया जा सकता है। यह प्लेटो के आदर्शवाद से मिलता है। प्लेटो के अनुसार यह जगत शाश्वत विचारों से परिपूरित है तथा विज्ञान की खोजें ज्ञान का अनावरण मात्र करती हैं। वे नवीन ज्ञान उत्पन्न नहीं करतीं। मनुष्य केवल अपना भरण-पोषण नहीं करता, वरन संस्कारी जीवन जीने के लिए शिक्षा प्राप्त करता है। उसकी आत्मानुभूति मनुष्य जाति द्वारा अर्जित संस्कृति को आत्मसात करने में निहित है। भारतीय व ग्रीक दर्शन के मिलते-जुलते ये उदात्त आदर्श भले ही कल्पना की उड़ान रहे हैं, फिर भी इस बात से इनकार नहीं किया जा सकता कि इन्हीं कल्पनाओं की धरती में यूनान व भारत की सभ्यता व संस्कृति पल्वित व पुष्पित हुई तथा सारे विश्व को सद्गुण, सदाचार व मानवता का पाठ पढ़ाया।

परिवर्तन प्रकृति का नियम है। सभ्यता और संस्कृति में कुछ वैसे भी स्वाभाविक परिवर्तन होते रहते हैं, किंतु जिस देश की धरती सैकड़ों वर्षों तक विदेशियों के हाथ में शिकस्त रही हो वहां बड़ी आसानी से संस्कृतिकरण की समस्याएं जन्म लेती हैं। इनमें भय, प्रभाव व अनुकरण तीन मूलभूत कारक होते हैं जो मिश्रित संस्कृति का निर्माण करते हैं। ऐसी दशा में व्यक्ति न तो अपनी संस्कृति में जी पाता है और न ही दूसरों की संस्कृति को पूरी तरह आत्मसात कर पाता है। फलतः संकीर्ण व निम्न कोटि के भ्रष्टाचारों की एक शृंखला समाज में बन जाती है। भारत का वर्तमान परिप्रेक्ष्य इसका जीता-जागता उदाहरण है। आज तक स्वतंत्र होते हुए भी न तो हम स्वतंत्र हैं और न स्वतंत्रता का अनुभव कर रहे हैं। सत्ता, सम्पत्ति और सुख की निरीह, नम्र कामना ने जन-जन को पथभ्रमित कर दिया है।

लोकतांत्रिक जामे के उन्मुक्त शोषण की समझ प्लेटो के मन में ढाई हज़ार वर्ष पूर्व ही आ गई थी। यही कारण था कि उसने सत्तासीन व्यक्ति को अर्थात शासक को पथभ्रष्ट होने से बचाने के लिए सम्पत्ति व पारिवारिक सुख से दूर रखा। ज्यामिति शास्त्र पर अनुसंधान तथा प्रशासकीय सेवाओं की स्तरीय परीक्षा प्रणाली प्लेटो की 'रिपब्लिक' का ही अनुकरण है। फर्क केवल इतना था कि प्लेटो ने इस परीक्षा प्रणाली को 20-50 वर्ष के मध्य एक लंबे अंतराल में व्यवस्थित किया था जबकि आज यह प्रारंभिक परीक्षा, मुख्य परीक्षा व साक्षात्कार के रूप में थोड़े समय में सीमित कर दी गई है। प्लेटो द्वारा विकसित सुरक्षा सेवा के क्षेत्र में 'ड्रिल' प्रणाली आज एन.सी.सी. के रूप में ख्याति प्राप्त है।

अरस्तू का दर्शन प्लेटो से थोड़ा अलग दिखाई देता है। उसने वैज्ञानिक तर्क के माध्यम से परिस्थितियों के अध्ययन का प्रयास किया है। अरस्तू ने राज्य के समग्र विकास के लिए सुशिक्षित नागरिकों के विकास पर सर्वाधिक ज़ोर दिया। आज साक्षरता का नारा केवल अक्षर ज्ञान मात्र से बुलंद किया जा रहा है। अरस्तू का मानना था कि अधूरी शिक्षा से व्यक्ति और दिग्भ्रमित हो जाता है। वर्तमान संदर्भ में यह संकेत प्रासंगिक भी है। हमारे देश में प्रति वर्ष करोड़ों रुपये साक्षरता, प्रौढ़ शिक्षा, सतत शिक्षा, दूरस्थ शिक्षा आदि के नाम पर खर्च किए जाते हैं। ऐसा इसलिए किया जाता है कि व्यक्ति की तर्कशक्ति, चिंतन शक्ति, निर्णय व निर्माण शक्ति आदि का सम्यक विकास हो तथा वह अपने समाज के व राष्ट्र के बारे में स्वस्थ निर्णय ले सके। इस भगीरथ प्रयास से इन उद्देश्यों की पूर्ति भारत में कितनी हुई है इसका आकलन बड़ी आसानी से आज की आर्थिक, सामाजिक, राजनीतिक व सबसे ज़्यादा नैतिक मूल्यों की लगातार गिरती साख के परिप्रेक्ष्य में देखा जा सकता है।

आंशिक उदाहरण के रूप में यदि भारत की वर्तमान राजनीतिक दशा का परीक्षण किया जाए तो पता चलता है कि 50 प्रतिशत जनता व्यापक प्रचार-प्रसार व प्रोत्साहन के बावजूद अपने मताधिकार का प्रयोग तक नहीं करती। इसका यह मतलब नहीं कि सभी नागरिक स्वतंत्र हैं। यह वास्तव में राष्ट्र व राष्ट्र के विकास के प्रति नागरिकों में जो लगाव होना चाहिए उसके ह्रास का प्रतीक है। इसके अतिरिक्त जातीय, सांप्रदायिक, क्षेत्रीय व भाषायी आधार पर सोच की संकीर्णता भारतीय मनःस्थिति में घर करती जा रही है। कुछ अच्छे पढ़े-लिखे लोग भी इसके शिकार हैं। यह हमारी प्रकृति-प्रदत्त स्वनिर्णय क्षमता के प्रति अभिशाप है। इसी ने राजनीतिक अस्थिरता व त्रिशंकु सदन जैसी असाध्य बीमारियों को पैदा किया है। इसी कारण अरस्तू स्वस्थ राजनीति में ऐसे नागरिकों की सहभागिता पर बल देता है जो शारीरिक व मानसिक आधार पर स्वस्थ हों, साथ ही वे भौतिक, आर्थिक अर्थात संपत्ति के क्षेत्र में भी संपन्न हों।

यूनानी दार्शनिक लोकतंत्र की कुछ कमज़ोरियों से अवगत थे। अरस्तू ने लोकतंत्र को कभी अच्छी शासन पद्धति नहीं माना। उसने अपने शासन के वर्गीकरण में प्रथम कोटि का शासन राजतंत्र, द्वितीय

कोटि का कुलीन तंत्र तथा तृतीय कोटि का लोकतंत्र बताया है। उसने लोकतंत्र के विकृत रूप को भीड़तंत्र कहा था। उसका मानना था कि इसमें शिक्षित, अशिक्षित, गंवार, अज्ञानी सभी प्रकार के नागरिक सत्ता के भागीदार होते हैं। ऐसी स्थिति में कानून एवं व्यवस्था के चुस्त-दुरुस्त होने का प्रश्न ही नहीं उठता। यही कारण है कि लोकतंत्र में सर्वाधिक भ्रष्टाचार दिखाई देता है। अरस्तू का यह विचार भले ही आधुनिक लोकतंत्र की प्रहरी स्वतंत्रता, समानता एवं भ्रातृत्व की भावना का विरोधी हो फिर भी तार्किक है। अरस्तू का तर्क था कि लोकतंत्र का अर्थ लोक कल्याण के लिए शासन करना है न कि राज्य के हर नागरिक को शासन में सहभागिता। उनका विचार था कि लोकतंत्र तभी अच्छा शासन हो सकता है जबकि उसमें सुशिक्षित, प्रबुद्ध, गुणवान व नीति निर्माण में चतुर प्रशिक्षित नागरिकों की सहभागिता हो। अरस्तू ने इन गुणों के अतिरिक्त सम्पत्ति अर्थात आर्थिक संपन्नता को भी सहभागी नागरिकों के लिए आवश्यक माना। यद्यपि उसके इस विचार की कटु आलोचना की गई, किंतु उसकी सोच तर्क के परे नहीं थी। हम भारतीय भी इस बात में विश्वास करते हैं कि "विभुक्षितंकिम् न करोति पापं" अर्थात एक लाचार, निरीह, गरीब, विपन्न कभी सत्कर्म सोच ही नहीं सकता क्योंकि उसका ध्यान तो सदैव अपनी निजी आवश्यकताओं की पूर्ति में लगा रहेगा।

न्याय के बारे में उसका विचार है कि कानून के पालन के अर्थ में न्याय एक पूर्ण गुण है। उसने इसे एक सामाजिक गुण की संज्ञा दी है। न्याय इतना महान है कि सुबह अथवा शाम का तारा भी इतना लुभावना नहीं होता। न्याय की प्रकृति प्रत्येक राज्य के अनुसार परिवर्तनीय है। उसका मानना है कि सभी वैध कार्य एक दृष्टि से न्यायसंगत कार्य होते हैं। भले कार्य अपने आप में ही सुखद होते हैं। न्याय के संबंध में सबसे महत्वपूर्ण बात यह है कि जो न्याय संगत हो वही समानता का अभिप्राय है। यह व्यक्तित्व के विकास के लिए समान अवसर की समानता के सकारात्मक पक्ष का समर्थन करता है, न कि प्रतिबंध रहित जन्म से समानता का। आज जो बहुमत की सत्ता लोकतंत्र की रीढ़ का कार्य कर रही है वह अरस्तू की 'पॉलिटिक्स' के 1290-ए में स्पष्ट उद्धृत है। इसमें संदेह नहीं कि यूनानी दार्शनिक जहां एक ओर भारतीय दर्शन के कर्मप्रधान राष्ट्रवाद व निष्काम कर्मयोग में आस्था रखते थे वहीं दूसरी ओर वे परिवर्तनशील राजनीतिक वास्तविकताओं के प्रति सजग भी थे। उनके चिंतन में आदर्शवादी दर्शन की कल्पना ही नहीं, संतोषजनक वैज्ञानिक तर्क भी समाहित था। उनमें मानव विद्या के प्रत्येक पक्ष के प्रति सहज, नैतिक एवं संयमित भाव था जो आज भी कम अनुकरणीय नहीं है। ❑

कक्षा के बाहर की शिक्षा

सत्य नारायण पंवार

अवकाश प्राप्त शिक्षा अधिकारी
68, गोल्फ कोर्स स्कीम
जोधपुर 342001

अधिकतर देखा गया है कि स्कूल का मूल्यांकन बोर्ड की परीक्षा के परीक्षाफल के आधार पर किया जाता है। इसीलिए स्कूल में कक्षा के अंदर की पढ़ाई अर्थात किताबी ज्ञान पर ज़्यादा ध्यान दिया जाता है। विद्यार्थियों के सर्वोन्मुखी विकास के लिए कक्षा के भीतर शिक्षण अधिगम के अलावा कक्षा के बाहर की शिक्षा यथा खेलकूद, सांस्कृतिक कार्यक्रम, एन.सी.सी., स्काउटिंग, शैक्षिक यात्राएं और अन्य सहपाठ्य-चारी क्रियाकलापों की शिक्षा भी ज़रूरी है। इन क्रियाकलापों को पाठ्यक्रम का हिस्सा नहीं माना जाता और स्कूलों में इन गतिविधियों पर ध्यान कम दिया जाता है। वास्तव में कक्षा के बाहर की शिक्षा के लिए इन गतिविधियों पर अधिक ध्यान दिया जाना चाहिए जिससे प्रत्येक विद्यार्थी अपनी रुचि के क्षेत्र में दक्षता प्राप्त कर प्रगति के पथ पर अग्रसर हो सके।

अधिकतर शिक्षण संस्थाओं में शिक्षण कार्य का आयोजन इस प्रकार होता है कि कक्षा में अध्यापक और शिक्षार्थी के बीच में अंतर्क्रिया होती रहे और शिक्षार्थी ज्ञान अर्जित करता रहे। इस किताबी ज्ञान के द्वारा किसी बोर्ड की परीक्षा तो पास की जा सकती है लेकिन दुनियादारी सीखने के लिए पठन-पाठन विधियों में कक्षा के बाहर के वातावरण का शिक्षण-सामग्री की तरह प्रयोग किया जाए, तो शिक्षार्थी को सोचने-समझने का और मूल्यांकन करने का अवसर मिलेगा। क्या पुस्तकीय ज्ञान ही शिक्षा है? कदापि नहीं। संसार, मानव और कार्यकलापों का पारस्परिक संयोग ही शिक्षा है।

आजकल कक्षा के बाहर की गतिविधियां जैसे – खेलकूद, सांस्कृतिक कार्यक्रम, एन. सी. सी., स्काउटिंग, शैक्षिक यात्राएं, नेचर क्लब, एडवेंचर क्लब, मशहूर ऐतिहासिक स्थलों, स्मारकों, औद्योगिक इकाइयों व कार्यालयों का अवलोकन हमारे स्कूल कार्यक्रम के आवश्यक अंग माने जाते हैं लेकिन इन्हें पाठयक्रम के आवश्यक हिस्सा नहीं माना जाता। स्कूलों में इन गतिविधियों पर कम ध्यान दिया जाता है। अधिकतर देखा गया है कि स्कूल के बोर्ड की परीक्षा के परीक्षाफल के आधार पर ही स्कूल का मूल्यांकन किया जाता है। इसलिए स्कूल में कक्षा के अंदर की पढ़ाई पर ज़्यादा ध्यान दिया जाता है। आधुनिक शिक्षा में किताबी ज्ञान पर ही अधिक ध्यान दिया जाता है और विद्यार्थियों की अभिरुचियों को विकसित करने के कार्यक्रम की न तो अध्यापक और न ही विद्यार्थी परवाह करते हैं।

इस प्रकार किताबी ज्ञान का शिक्षा के द्वारा कुछ बुद्धिजीवी विद्यार्थी ही फायदा उठा पाते हैं, पर केवल महाज्ञानी बनने से जीवन में सफलता नहीं मिलती। कक्षा के बाहर खुले वातावरण में विद्यार्थियों की अन्य अभिरुचियों को विकसित किया जाना चाहिए जिससे वे दुनिया के विभिन्न क्षेत्रों में अच्छा काम करके अपना नाम कमा सके। ऐसी परिस्थितियों में विद्यार्थियों को स्कूल की कक्षा के बाहर ऐसे अवसर प्रदान किए जाने चाहिए जिससे उनमें गुणात्मक परिवर्तन आए और वे अपने भविष्य में सामाजिक जीवन को सफल बना सकें। कक्षा के बाहर के इन क्रियाकलापों के द्वारा छात्र में निम्नलिखित आवश्यक परिवर्तनों का विकास किया जा सकता है :

❑ **शारीरिक शक्ति और चुस्ती का विकास :** मस्तिष्क के लिए अध्ययन की उतनी ही आवश्यकता है जितनी शरीर को व्यायाम की। अगर कक्षा के बाहर की सभी गतिविधियों को खासकर खेलकूद को सही ढंग से कार्यान्वित किया जाए तो विद्यार्थियों के शरीर के तंतु और सभी इंद्रियों की कसरत होगी। विद्यार्थियों का शरीर मज़बूत और फुर्तीला हो जाएगा। इतना ही नहीं शरीर स्वस्थ होगा तो मानसिक स्वास्थ्य भी ठीक रहेगा और विद्यार्थी पढ़ने में होशियार होगा। शरीरिक गतिविधियों में सक्रिय भाग लेने से विद्यार्थियों में स्व-अनुशासन और सहनशीलता की भावना उत्पन्न होगी जो उनके जीवन के लिए आवश्यक है। स्वस्थ और सुडौल शरीर वाला ही अपनी और राष्ट्र की रक्षा कर सकता है।

❑ **वातावरण से शिक्षा :** कक्षा के बाहर के क्रियाकलापों में भाग लेते समय विद्यार्थी सामाजिक और प्राकृतिक वातावरण के संपर्क में आएंगे। संपर्क में आने से वे अपनी अधिगम शैलियों का प्रयोग करेंगे और वातावरण के द्वारा सीखने का प्रयत्न करेंगे। इतना ही नहीं वातावरण के विभिन्न स्रोतों का समाज और अपनी आवश्यकताओं के लिए प्रयोग करेंगे जिससे वे कक्षा में विज्ञान और सामाजिक ज्ञान को आसानी से सीख सकेंगे। एनवायरमेंटल एजूकेशन के द्वारा छात्र अपना विकास कर सकता है। यह शिक्षा स्व-शिक्षा के लिए उन्हें प्रेरित करती है।

❑ **मानवीय मूल्यों का विकास :** छात्रों को सक्रिय रूप से कक्षा के बाहर की गतिविधियों में भाग लेने से मानवीय मूल्यों जैसे समय की पाबंदी, फुर्तीलापन, सहयोग, अनुशासन, सहनशीलता, एकाग्रता, भावनात्मक एकता और राष्ट्र प्रेम का संपूर्ण विकास होता है। इतना ही नहीं इन गतिविधियों में सक्रिय भाग लेने से विद्यार्थियों में मानवीय गुणों जैसे साहस, सच्चाई, दूसरों के लिए आदर, लगन और वातावरण और लोगों की भावना के अनुरूप अपने को ढालने की काबिलियत का विलय होता है जो उन्हें दुनियादारी निभाने के लिए सीखना आवश्यक है।

इतना ही नहीं कैंपों में विद्यार्थी अपने आप पर भरोसा करना सीख जाता है। इन कैंपों में वह श्रम की महत्ता, सामूहिक रूप से कार्य करने की क्षमता और सुखी सामाजिक वातावरण उत्पन्न करने के तरीके सीख जाता है। सबसे बड़ी बात है कि छात्र कैंपों में अपने अंदर के गुणों के द्वारा

नेता बनने के बीजों को पौधों के रूप में विकसित कर सकता है। इन कैंपों में सभी विद्यार्थी हिलमिल कर रहने की कला सीखते हैं जो किताबों को पढ़ने से हासिल नहीं होती। सच्ची शिक्षा व्यक्ति को उदार बनाती है।

❑ **जोखिम उठाने की आदत :** कमांडर सतवीर ने लिखा है कि विद्यार्थियों में नपी-तुली जोखिम उठाने की आदत का विकास होना चाहिए क्योंकि यह जीवन का आवश्यक तत्व है। बिना जोखिम उठाए मनुष्य उत्कर्ष की सीढ़ी पर नहीं चढ़ सकता और अपना नाम नहीं कमा सकता। बिना नपी-तुली जोखिम उठाना नासमझ लोगों का काम होता है।

दुनिया में इसी आदत ने मनुष्यों को नई खोज के लिए प्रेरित किया। इसी आदत ने मनुष्य को नई मुश्किल जगहों का पता लगाने, नए अनुभवों के आधार पर लिखने के लिए हमेशा प्रेरित किया है। हमारे आधुनिक विद्यार्थियों में इस आदत का विकास करना आवश्यक है जिससे वे नपातुला जोखिम उठाकर नई इंडस्ट्रीज़ खोल अपने-आपको स्वरोज़गार में लगा सकें। सच्ची शिक्षा व्यक्ति को आत्म निर्भर बनाती है।

❑ **आनंद देने वाला अनुभव :** लगातार कक्षा की चहारदीवारी में शैक्षिक अधिगम के पश्चात कक्षा के बाहर खुली हवा में सीखने के अनुभव से विद्यार्थियों को अत्यधिक आनंद आता है। इससे पता चलता है कि खुले वातावरण में बच्चों के लिए आनंद का स्रोत अधिक है। प्रकृति की गोद में और प्यार के झूलने में वह आनंद विभोर हो उठता है।

स्कूलों में आज की वस्तुस्थिति

अधिकतर स्कूलों में कम से कम निम्नलिखित गतिविधियां विद्यमान हैं :

1. सांस्कृतिक कार्यक्रम 2. खेल-कूद
3. स्काउटिंग।

खेलकूद का शौक रखने वाले छात्र ही शाम को अपना कोई खेल खेलते हैं और स्कूल के कार्यक्रम में फिज़ीकल एजूकेशन के आधे घंटे के पीरियड में न तो वे कोई सुव्यवस्थित खेल खेल सकते हैं और न पी.टी. कर सकते हैं क्योंकि वे स्कूल की वर्दी में चमड़े के जूते पहने रहते हैं। अधिकतर देखा गया है कि शारीरिक शिक्षक उन्हें एक बार ज्ञान देकर गप्प लगाते हैं। बड़े-बड़े शहरों के स्कूलों में स्थानाभाव के कारण खेलने के मैदान भी उपलब्ध नहीं है। फिर छात्रों को खेलने के लिए मैदान न होने के कारण खेलने का अवसर भी नहीं मिलता। अधिकतर छात्रों को खेलकूद अच्छा नहीं लगता क्योंकि बोर्ड की परीक्षा में इसके अंक परीक्षाफल में नहीं जुड़ते और कुछ अभिभावक भी अपने बच्चों को खेलने के लिए मना करते हैं जिससे उनके बच्चों को कोई चोट न लग जाए। हालांकि खेलकूद पाठयक्रम का अभिन्न अंग है फिर भी इस गतिविधि में न अध्यापक और न ही विद्यार्थी रुचि लेते हैं।

सेवा और परोपकार की भावना का विकास करने के लिए स्काउटिंग और गाइडिंग की गतिविधियां स्कूलों में होती हैं लेकिन इसमें कोई विद्यार्थी रुचि नहीं लेता क्योंकि इसके अंक वार्षिक परीक्षा में नहीं जुड़ते और स्कूल के टाइमटेबल में

इसका कालांश भी निर्धारित नहीं है। कुछ अध्यापक स्कूल के गिने-चुने छात्रों को स्काउटिंग और गाइडिंग का शिक्षण देते हैं लेकिन इन अध्यापकों को कोई अतिरिक्त भत्ता नहीं मिलता। इन गतिविधियों के द्वारा कुछ अध्यापक ही कुछ छात्रों को ट्रेनिंग दे पाते हैं जिसके द्वारा ये छात्र मानव-सेवा और परोपकार करना सीखते हैं। अभिभावक बच्चों को कैंप में भेजना नहीं चाहते जबकि कैंप में बच्चा व्यावहारिक जीवन सीखता है।

कुछ अच्छे स्कूलों में जहां मैदान उपलब्ध हैं, स्कूल में उपरोक्त कक्षा के बाहर की गतिविधियों के अलावा निम्नलिखित गतिविधियों का प्रावधान भी है :

- एन.सी.सी.
- यूनेस्को क्लब
- नेचर क्लब
- एडवेंचर क्लब
- साइंस क्लब
- फोटोग्राफी क्लब
- ऐजूकेशनल एक्सकर्शन
- ऐजूकेशनल टूर्स
- शहर की ऐतिहासिक व औद्योगिक इकाइयों और कार्यालयों का अवलोकन

कक्षा के बाहर की शिक्षा में सुधार लाने के सुझाव

- प्रत्येक सेकंडरी और हायर सेकंडरी स्कूल में एक एन.सी.सी. ग्रुप होना चाहिए और छात्रों को सुचारु रूप से ट्रेनिंग देकर उन्हें सेना में भर्ती होने के लिए प्रेरित करना चाहिए। एन.सी.सी के छात्र इस ट्रेनिंग से और समाज-सेवा के कैंपों के माध्यम से समाज के संपर्क में आकर अच्छे नागरिक बनेंगे।
- खेलकूद के शिक्षकों को स्कूल कैंपस में मकान मिलना चाहिए जिससे वे छात्रों को स्कूल टाइम के आलावा सुबह व शाम खेल खेलने में पारंगत बना सकें।
- स्कूल के सभी अध्यापकों को कक्षा में पढ़ाने के अलावा कोई न कोई कक्षा के बाहर की गतिविधियों में यथा—सांस्कृतिक कार्यक्रम, स्काउटिंग इत्यादि की ट्रेनिंग लेनी चाहिए जिससे ज़्यादा से ज़्यादा छात्रों को कक्षा के बाहर की शिक्षा मिल सके और वे समाज की गतिविधियों में सक्रिय भाग ले सकें। एन.सी.सी. के इंसट्रक्टर की तरह इन अध्यापकों को ऐमूरेशन मिलना चाहिए जिससे वे अपने काम में रुचि लें।
- कक्षा के बाहर की शिक्षा के क्षेत्र में होशियार छात्रों को वार्षिक परीक्षा में 5-10 का इज़ाफा दिया जाए। इतना ही नहीं उन्हें स्कोलरशिप भी दी जाए जिससे वे अपने क्षेत्र में नाम कर सकें।
- स्कूल के टाइम टेबल में एक अंतिम कालांश निश्चित किया जाए जिससे सभी अध्यापक और सभी छात्र किसी न किसी कक्षा के बाहर की शिक्षा की गतिविधियों में भाग लेंगे जिससे वे जीवन के किसी खास क्षेत्र में सफल हो सकें तथा सभी छात्रों को अपनी रुचि का संपूर्ण विकास करने का अवसर मिले।

- कुछ स्कूलों ने खेलकूद में होशियार छात्रों के लिए होस्टल की व्यवस्था कर रखी है जहां उन्हें खास ट्रेनिंग देकर उस खेल में होशियार बनाया जाता है। इसी प्रकार सभी स्कूलों में कोई न कोई आउटडोर एक्टिविटी के लिए होस्टल बनने चाहिए जिससे बच्चों को खेलों के अलावा पर्वतारोहण, समाज सेवा, नृत्य, अभिनय इत्यादि की ट्रेनिंग मिलती रहे।
- सहपाठ्यचारी गतिविधियों को आयोजित करते समय ज़्यादा से ज़्यादा छात्रों की भागीदारी का ध्यान रखना चाहिए।
- प्राइमरी कक्षाओं के छात्रों के लिए निम्नलिखित कक्षा के बाहर की शिक्षा का प्रावधान होना चाहिए :
  1. स्कूल के मैदान में खेलकूद, पी.टी., ड्रिल कराना।
  2. चिड़ियाघर दिखाना।
  3. बडे-बड़े बाग बगीचे, ऐतिहासिक स्थान और पुरातत्व विभाग दिखाना।
  4. रेलवे स्टेशन और एयरपोर्ट दिखाना।
  5. रेडियो स्टेशन, टी.वी. सेंटर और टेलीफोन एक्सचेंज दिखाना।
  6. औद्योगिक इकाइयां, फार्म, मशहूर कार्यालय, कोर्ट, पुलिस स्टेशन, जेल आदि दिखाना।
  7. मशहूर बाज़ार, पोस्ट आफिस एवं बैंक के कार्य दिखाते हुए समझाना।

कक्षा के बाहर की शिक्षा में अध्यापकों को सक्रिय भाग लेकर प्रत्येक पहलू समझाना चाहिए जिससे बच्चों की अधिगम शैली का कक्षा में उपयोग हो सके। प्राइमरी के छोटे बच्चों को घूमने और देखने में आनंद आता है और वे नई वस्तुओं को देखने, समझने, और नई बात सीखने में माहिर हो जाते हैं।

स्कूलों की कक्षाओं में छात्रों को जो शिक्षा मिलती है वह शिक्षा नहीं अपितु शिक्षा का साधन मात्र है। कक्षा में छात्र दूसरों (अध्यापकों) से शिक्षा प्राप्त करता है लेकिन वातावरण में स्वयं शिक्षा प्राप्त कर सकता है।

अध्यापकों द्वारा पढ़ाने और विद्यार्थियों द्वारा कक्षा में किताबी ज्ञान प्राप्त करने से वे विभिन्न राष्ट्र स्तर की प्रतिस्पर्धा की लिखित परीक्षाएं तो पास कर लेंगे लेकिन अन्य क्षेत्रों में शायद पीछे रह जाएं। ऐसी परिस्थिति में विद्यार्थियों का सर्वोमुखी विकास के लिए कक्षा के भीतर के शिक्षण-अधिगम के अलावा कक्षा के बाहर की शिक्षा को भी उतना ही महत्व दिया जाना चाहिए। इससे विद्यार्थी अपनी रुचि के क्षेत्र में अपनी दक्षता से अपना नाम ऊंचा कर सकेगा। प्रत्येक विद्यार्थी को चाहिए कि वह एक अच्छा खिलाड़ी बने, परीक्षा में 60 प्रतिशत अंक प्राप्त करें तभी विद्यालय अपने लक्ष्यों को पूरा कर पाएगा। विद्यालयों में शिक्षा ग्रहण किए हुए छात्र सिर्फ इंजीनियर, डाक्टर या प्रशासक ही न बनें बल्कि बड़े नेता, अभिनेता, उद्योगपति, वैज्ञानिक, खिलाड़ी भी बनें और अन्य सभी महत्वपूर्ण क्षेत्रों में अपना नाम कमाएं जिससे हमारे समाज और देश का नाम भी ऊंचा हो। ❑

छात्रों में राष्ट्रीय एकता के भाव उत्पन्न करने के उपाय

राम सूरत त्रिपाठी

नरैनी रोड, अतर्रा (बांदा)
उत्तर प्रदेश 210201

आज देश में धर्मवाद, संप्रदायवाद, जातिवाद, भाषावाद, क्षेत्रवाद, भाई-भतीजावाद आदि पनप रहे हैं जो राष्ट्रीय एकता और अखंडता को आघात पहुंचा रहे हैं। ऐसे वादों को समूल नष्ट करने की ज़रूरत है। ऐसी स्थिति में हम शिक्षा के माध्यम से छात्रों की एक ऐसी सेना तैयार कर सकते हैं जो राष्ट्रीय एकता की भावना से परिपूर्ण हो तथा राष्ट्रीय एकता को क्षति पहुंचाने वाले वादों के विरुद्ध संघर्ष करने में आगे आए। इसके लिए शिक्षकों व अभिभावकों को एकजुट प्रयास करना होगा।

पंडित नेहरू ने कहा था, "मैं भारत की एकता पर ज़ोर देता हूं, लेकिन मेरा मतलब राजनैतिक एकता नहीं है जो हम पहले ही पा चुके हैं। मेरा ज़ोर तो भावात्मक एकता पर है। ऐसी एकता जिसमें लोग दिलो-दिमाग से जुड़े रहें और अलगाव की भावना ही समाप्त हो जाए।" पंडित नेहरू के इस कथन के आधार पर हम कह सकते हैं कि राष्ट्रीय एकता ही राष्ट्र के जीवन की आत्मा है। आज अनेक कारणों से हमारे देश में धर्मवाद, जातिवाद, संप्रदायवाद, भाषावाद, क्षेत्रवाद आदि तत्व संपूर्ण समाज को दूषित कर राष्ट्रीय एकता को आघात पहुंचा रहे हैं। हमें ऐसे तत्वों के विरुद्ध लड़कर उन्हें समूल नष्ट करना होगा। इसके लिए हमें देश के भावी कर्णधार-छात्रों की एक ऐसी सेना तैयार करनी होगी जो इन घातक तत्वों से प्रभावित न होकर देश का मार्ग प्रशस्त करें।

हमारे देश के संविधान में राष्ट्रीय एकता के तीन आधारभूत तत्व स्वतंत्रता, समता और बंधुत्व बताए गए हैं। इनमें बंधुत्व राष्ट्रीय एकता का साधक है। वास्तव में राष्ट्रीयता एक मनःस्थिति होती है जिसमें नागरिक संकीर्ण निष्ठा व अपने हितों से ऊपर उठकर व्यापक राष्ट्रीय एकता को धारण कर समाज में राष्ट्रीय एकता के भाव स्थापित करते हैं। इस एकता की प्राप्ति केवल भाषण मात्र से संभव नहीं हैं अपितु इसके लिए सतत प्रयास व ठोस रणनीति की आवश्यकता होती है। राष्ट्रीय एकता की भावना विकसित करने में शिक्षा की भूमिका महत्वपूर्ण होती है। डा. राधाकृष्णन ने भी कहा था कि शिक्षा के द्वारा

लोगों के दिलो-दिमाग में राष्ट्रीय एकता के भाव उत्पन्न किए जा सकते हैं। राष्ट्रीय एकता की गजेंद्र गाड़कर उपसमिति (1968) ने भी संस्तुति की थी कि प्राथमिक शिक्षा से उच्च शिक्षा तक छात्रों में भारतीयता, समता, समभाव, प्रजातांत्रिक विचार आदि उत्पन्न करने के प्रयास किए जाने चाहिए। राष्ट्रपिता महात्मा गांधी व अन्य समाज सुधारक राष्ट्रीय नेताओं ने भी राष्ट्रीयता जागृत करने की क्षमता शिक्षा में ही पाई थी। राष्ट्रीय शिक्षा नीति (1986) भी ऐसे क्रियाकलापों पर ज़ोर देती है जिनसे छात्रों में राष्ट्रीय एकता के भाव मज़बूत हों।

छात्रों में राष्ट्रीय एकता के भाव उत्पन्न करने में शिक्षकों व अभिभावकों की भूमिका महत्वपूर्ण होती है। साथ-साथ ऐसी पाठ्यक्रम सहगामी क्रियाएं भी अपेक्षित हैं जो छात्रों में राष्ट्रीय एकता के भाव उत्पन्न कर सकें।

शिक्षक को स्वयं में समेकित व्यक्तित्व, लोकतांत्रिक विचारों वाला, धर्म, जाति व क्षेत्र से निरपेक्ष तथा राष्ट्रीय दृष्टिकोण वाला होना चाहिए जिससे कि वह छात्रों में स्वयं के गुण विकसित कर उन्हें सच्चे नागरिक व देश-भक्त बना सकें। छात्रों पर शिक्षक के व्यक्तित्व का व्यापक प्रभाव पड़ा करता है। अतः शिक्षक को छात्र समुदाय के समक्ष अपने को एक आदर्श व अनुकरणीय व्यक्ति के रूप में प्रस्तुत करना चाहिए। बच्चों में राष्ट्रीयता के भाव उत्पन्न करने में अभिभावकों की भूमिका भी कम महत्वपूर्ण नहीं होती। भारतीय समाज की बहुआयामी विशेषताओं को ध्यान में रखते हुए अभिभावकों को अपने बच्चों के सम्मुख भारतवासियों के विभिन्न धर्मों, विश्वासों, रीति-रिवाजों, त्योहारों, उत्सवों, परंपराओं, भाषा, पहनावे व अन्य ज्ञात बातों का गुणगान करना चाहिए, जिससे बच्चों में अपने देश व देशवासियों के प्रति लगाव व प्रेम के भाव उत्पन्न हो सकें। राष्ट्रीय एकता के साथ शिक्षा का संबंध जोड़ने में विद्यालयों को एक समन्वयक का कार्य करना चाहिए। ऐसी शिक्षा प्रणाली विकसित की जानी चाहिए जो छात्रों में बंधुत्व, एकता, सद्भाव, धर्मनिरपेक्षता, कर्त्तव्यपरायणता आदि भाव विकसित करने में सहायक सिद्ध हो।

पाठ्यक्रमों द्वारा राष्ट्रीय एकता का विकास

विद्यालयों के पाठ्यक्रम व पाठ्यक्रम सहगामी क्रियाकलापों द्वारा छात्रों में राष्ट्रीय एकता के भाव निम्न प्रकार से विकसित किए जा सकते हैं :

❑ **भाषा शिक्षण :** भाषा विषयों के पाठों में राष्ट्रीयता से संबंधित निबंध, नाटक, कहानी व गीत होने चाहिए। इन पाठों से देश प्रेम, देश सेवा, समाज सेवा, बंधुत्व, धर्मनिरपेक्षता, जाति निरपेक्षता व सांप्रदायिक सद्भाव की प्रेरणा मिलनी चाहिए। पुस्तकों में ऐसे पाठ भी हों जिनसे देश के प्रमुख त्योहारों, उत्सवों, परंपराओं व रीति-रिवाजों का परिचय मिलता हो। पाठों की लेखन शैली इस प्रकार की हो जो छात्रों में अपनत्व के भाव जागृत करे, जैसे हमारे देशवासी, हमारे त्योहार, हमारे धार्मिक ग्रंथ आदि शब्दों का भरपूर प्रयोग हो। शिक्षक की शिक्षण शैली ओजस्वी हो। छात्र

शिक्षक के कथन को आगे सुनने के लिए आतुर रहें। इससे छात्रों के मस्तिष्क पर शिक्षक के कथनों का स्थायी प्रभाव पड़ेगा।

❑ **इतिहास शिक्षण :** इतिहास विषय में मात्र घटनाओं का वर्णन न रहे। अपितु इस विषय में सांस्कृतिक धरोहर, भारतीय संस्कृति की विशेषताएं, प्राचीन सभ्यताएं, आर्यों की भूमि भारत, विभिन्न धर्मों की मूल शिक्षा, अनेकता में एकता, हमारे ऋषि-मुनि, प्रसिद्ध समाज सुधारक आदि विषयों से संबंधित पाठ अवश्य होने चाहिए। ऐसे पाठों को इस शैली में पढ़ाया जाए कि छात्रों के हृदय पटल में अपनी देशज संस्कृति व समाज के प्रति प्रेम उत्पन्न हो तथा वह विशुद्ध भारतीय बनने को प्रेरित हो। युद्धों की शिक्षण शैली ऐसी हो कि छात्र युद्धों को अतीत की घटनाएं मात्र समझें। उसमें किसी प्रकार के बदले के भाव या सांप्रदायिक भाव उत्पन्न न हों।

❑ **नागरिक शास्त्र शिक्षण :** इस विषय के माध्यम से छात्रों में राष्ट्रीयता के भाव अधिक आसानी से भरे जा सकते हैं। नागरिक शास्त्र के पाठों में देश के प्रति हमारे (छात्रों के) कर्त्तव्य, देशवासियों के कर्त्तव्य व अधिकार, अच्छे नागरिक के गुण, अच्छी नागरिकता से समाज को व देश को लाभ, देश की महत्वपूर्ण समस्याओं व उनके निराकरण में हमारा कर्त्तव्य, देश की विकास नीति व उसके गुण आदि पाठ होने चाहिए।

❑ **भूगोल शिक्षण :** भूगोल के पाठ्यक्रम में हमारे पर्वत, हमारी नदियां, हमारे वन, हमारी फसलें, हमारे खनिज, हमारे उद्योग, हमारे ग्राम, हमारे नगर, यातायात के हमारे साधन, हमारी बहुउद्देशीय योजनाएं, प्रादेशिक निर्भरता आदि पाठ होने चाहिए। अनेक आवश्यकताओं के लिए एक क्षेत्र दूसरे पर निर्भर होता है। उचित उदाहरण देते हुए क्षेत्रीय एकता सिद्ध करने के प्रयास किए जाने चाहिए।

❑ **विज्ञान शिक्षण :** विज्ञान विषय में हमारे वन, हमारा जल, हमारी वायु, हमारे पशु-पक्षी, हमारा स्वास्थ्य, हमारा सौर मण्डल, हमारी ऊर्जा आदि पाठ होने चाहिए। इन पाठों के शिक्षण में प्राकृतिक संसाधनों की भूमिका बताते हुए उनके संरक्षण पर बल दिया जाना चाहिए। ये पाठ इस शैली में पढ़ाए जाएं कि छात्रों के मन में प्राकृतिक संसाधनों के प्रति प्रेम उत्पन्न हो सके।

पाठ्यक्रम सहगामी क्रियाकलापों द्वारा राष्ट्रीय एकता का विकास

विद्यालयों में ऐसे पाठ्यक्रम सहगामी क्रियाकलाप संपन्न होने चाहिए जो छात्रों व स्थानीय व्यक्तियों में राष्ट्रीयता के भाव उत्पन्न करे। संपूर्णानंद समिति ने छात्रों में एकता के भाव उत्पन्न करने के उद्देश्य से स्कूल वर्दी, प्रार्थना स्थल में छात्रों का प्रतिदिन एकत्र होना, नाटक, पर्यटन, विद्यालय सुधार आदि क्रियाएं प्रस्तावित की थीं। इन क्रियाओं के अतिरिक्त किसी आपदा के समय में भी पीड़ित क्षेत्र के लिए चंदा इकट्ठा करना, अंतर्विद्यालयीय वाद-विवाद प्रतियोगिता में भाग लेना, छात्र-उत्सवों में भाग लेना, स्काउट शिविरों में भाग लेना, स्थानीय समस्याओं के निदान में सहयोग करना, समाज के लिए सप्ताह में एक दिन श्रमदान करना आदि क्रियाएं भी छात्रों द्वारा

संपन्न कराई जानी चाहिए। इनसे छात्रों व स्थानीय व्यक्तियों में भी राष्ट्रीयता के भाव उत्पन्न होंगे। राष्ट्रीय शैक्षिक अनुसंधान व प्रशिक्षण परिषद्, नई दिल्ली ने भी छात्रों में राष्ट्रीय एकता कायम करने के उद्देश्य से कई क्रियाकलाप संपन्न किए जाने का सुझाव प्रस्तुत किया है जिनमें प्रमुख निम्न हैं :

- ❑ राष्ट्रीय व देशभक्ति के गीतों का सामूहिक गायन
- ❑ राष्ट्रीय ध्वज को सम्मान
- ❑ विद्यालय परिसरों में राष्ट्रीय त्योहारों का आयोजन
- ❑ राष्ट्रीय महापुरुषों के जन्म-दिवस समारोहों का आयोजन
- ❑ अंतर्राज्यस्तरीय मित्रता विकसित करना
- ❑ शैक्षिक पर्यटन कार्यक्रम बनाना
- ❑ धार्मिक सहिष्णुता के कार्यक्रम आयोजित करना
- ❑ सांस्कृतिक कार्यक्रमों का आयोजन

प्रदर्शनी विकसित करना

विद्यालयों में विभिन्न प्रकार के चार्ट व प्रतिमानों (मॉडलों) की प्रदर्शनी विकसित की जानी चाहिए जिनसे राष्ट्रीय एकता परिलक्षित हो। ऐसे कार्य हेतु राष्ट्रीय शैक्षिक अनुसंधान और प्रशिक्षण परिषद्, नई दिल्ली ने कई प्रकार के प्रदर्शनों का सुझाव प्रस्तुत किया है। इन सुझावों के आधार पर जो कार्य संपन्न किए जा सकते हैं वे हैं :

- ❑ भारत के मानचित्र में सभी राज्यों व केंद्रशासित प्रदेशों का सीमांकन
- ❑ देश के विभिन्न भागों में विकसित गृह-निर्माण शैली का प्रदर्शन
- ❑ देश के विभिन्न भागों के निवासियों के उत्सवों, नृत्यों व रीति-रिवाजों का प्रदर्शन
- ❑ भारत के मानचित्र पर विभिन्न फसलों, खनिजों, शक्ति संसाधनों, रेलमार्गों व सड़कों का प्रदर्शन
- ❑ भारत के मानचित्र पर विभिन्न वस्तुओं के आंतरिक परिवहन का प्रदर्शन जिससे विभिन्न क्षेत्रों की पारस्परिक निर्भरता प्रकट हो।
- ❑ भारत के मानचित्र में देश की पर्वत शृंखलाओं व नदियों का प्रदर्शन
- ❑ देश के विभिन्न भागों में मिलने वाले पशुओं व पक्षियों का चित्र-निर्माण
- ❑ भारत व अन्य राज्यों के मानचित्र में प्रमुख धार्मिक केंद्रों, पर्यटनस्थलों, ऐतिहासिक महत्व के स्थानों का प्रदर्शन
- ❑ विभिन्न धर्मग्रंथों से लिए गए उपदेशात्मक वाक्यों का लेखन आदि।

उपर्युक्त सभी प्रदर्शन तैयार कराकर छात्रों को प्रदर्शनों के उद्देश्य बताए जाने चाहिए। वर्ष में कम से कम एक बार सार्वजनिक प्रदर्शन किया जाना चाहिए तथा प्रदर्शनों की व्याख्या के लिए छात्रों को शिक्षकों द्वारा उचित प्रशिक्षण दिया जाना चाहिए। प्रदर्शनी के समय छात्र ही अपने मित्रों, अभिभावकों व अन्य व्यक्तियों के सम्मुख प्रदर्शनों की व्याख्या करें। यदि संभव हो तो वर्ष में एक बार विद्यालय से बाहर दूरस्थ स्थानों पर भी इस प्रदर्शनी का आयोजन किया जाना चाहिए। ऐसे प्रदर्शनों से छात्रों व दर्शकों में राष्ट्रीयता के भाव उत्पन्न होंगे। ❑

प्रयुक्त उत्तर पुस्तिकाओं की संख्या का निष्पत्ति पर प्रभाव : एक अध्ययन

सुभाष चंद्र अग्रवाल
सुषमा तिवारी

शिक्षाशास्त्र विभाग
छत्रपति शाहू जी महाराज वि. वि., कानपुर

परीक्षा शिक्षा प्रणाली का एक महत्वपूर्ण अंग है, जिसका प्रमुख उद्देश्य छात्र की संपूर्ण सत्र की उपलब्धि को जानना है। 'परीक्षा में कम उत्तर पुस्तिकाओं का प्रयोग करने वाले छात्रों के प्राप्तांक अधिक उत्तर पुस्तिकाओं का प्रयोग करने वाले छात्रों के प्राप्तांकों से कम होते हैं,' इस प्रचलित धारणा के परीक्षण के लिए प्रस्तुत अध्ययन किया गया। अध्ययन का निष्कर्ष उक्त धारणा के पक्ष में रहा। इससे वर्तमान परीक्षा प्रणाली की प्रासंगिकता पर एक प्रश्न चिह्न लग जाता।

परीक्षा प्राचीन काल से ही शिक्षा प्रणाली का एक महत्वपूर्ण अंग रही है। परीक्षाओं के माध्यम से यह जानने का प्रयास किया जाता है कि बालक ने संपूर्ण सत्र में कितना ग्रहण किया है। सामान्यतः परीक्षाएं वर्ष के अंत में ली जाती हैं। अतः छात्र पूरे वर्ष भर प्रयत्नशील रहते हैं कि वे परीक्षा में अधिक से अधिक अंक प्राप्त करें। अधिकतम सफलता प्राप्त करने के लिए वे जितने तरीके अपना सकते हैं, अपनाते हैं।

एक लंबे समय से छात्रों, अभिभावकों तथा शिक्षा से जुड़े अन्य सभी लोगों के मध्य यह धारणा रही है कि परीक्षा में प्राप्त किए जाने वाले अंकों का संबंध अन्य बातों के अतिरिक्त छात्रों द्वारा परीक्षा भवन में प्रयुक्त की जाने वाली उत्तर पुस्तिकाओं की संख्या से भी है अर्थात परीक्षा में एक निश्चित समय में छात्र जितनी अधिक कापियों का प्रयोग करता है, उसे उतने ही अधिक अंक प्राप्त होते हैं। गुप्ता एवं अग्रवाल (1982) ने भाषा (अंग्रेज़ी एवं हिंदी) विषयों में उपलब्धि एवं लेखन गति के बीच सह-संबंध जानने का प्रयास किया और कहा कि इस क्षेत्र में अधिक सावधानी एवं गहनता से अध्ययन किया जाना चाहिए।

प्रायः यह देखने को मिलता है कि कुछ छात्र मात्र 'ए' या एक 'बी' कापी का ही प्रयोग करते हैं जबकि बहुत से छात्र हैं, जो 3 या 4 या उससे भी अधिक 'बी' कापी का प्रयोग करते हैं। ऐसा क्यों होता है? क्या उनको ऐसा लगता है कि अधिक पुस्तिकाओं के प्रयोग से परीक्षाओं में अधिक अंक प्राप्त किए जा सकते हैं? क्या प्रचलित

धारणा सही है? जबकि परीक्षा के संप्रत्यय के अनुसार परीक्षाएं मानसिक योग्यता का मापन करती हैं अर्थात जिन शैक्षिक उद्देश्यों को लेकर परीक्षाएं आयोजित की जाती हैं, उन उद्देश्यों में से छात्र ने कितना प्राप्त किया है यह जानने का प्रयास परीक्षाओं के माध्यम से किया जाता है। तब क्या वर्तमान परीक्षाएं अपने उद्देश्यों को पूरा कर रही हैं? शायद नहीं। अतः अनुसंधानकर्ताओं ने प्रस्तुत अध्ययन द्वारा यह जानने का प्रयास किया कि क्या परीक्षाओं में कम कापी प्रयुक्त करने वाले छात्रों तथा अधिक कापी प्रयुक्त करने वाले छात्रों एवं उनके प्राप्तांकों में कोई संबंध है या नहीं।

उद्देश्य

- ❑ विभिन्न प्रश्नपत्रों में कम उत्तर पुस्तिकाओं एवं अधिक उत्तर पुस्तिकाओं का उपयोग करने वाले छात्रों के प्राप्तांकों के मध्य अंतर जानना।
- ❑ सभी प्रश्नपत्रों में एक साथ कम उत्तर पुस्तिकाओं एवं अधिक उत्तर पुस्तिकाओं का उपयोग करने वाले छात्रों के प्राप्तांकों के मध्य अंतर जानना।

परिकल्पना

❑ विभिन्न प्रश्नपत्रों में कम उत्तर पुस्तिकाओं का प्रयोग करने वाले छात्रों के प्राप्तांक अधिक उत्तर पुस्तिओं का प्रयोग करने वाले छात्रों के प्राप्तांकों से कम होंगे।

❑ सभी प्रश्नपत्रों में एक साथ कम उत्तर पुस्तिकाओं का प्रयोग करने वाले छात्रों के प्राप्तांक अधिक उत्तर पुस्तिकाओं का प्रयोग करने वाले छात्रो के प्राप्तांकों से कम होंगे।

जनसंख्या एवं न्यादर्श

छत्रपति शाहू जी महाराज विश्वविद्यालय, कानपुर परिसर के वर्ष 1998 की एम. एड. परीक्षा में सम्मिलित समस्त छात्र इस अध्ययन की जनसंख्या एवं न्यादर्श रहे।

अध्ययन विधि

वर्ष 1998 की छत्रपति शाहू जी महाराज विश्वविद्यालय, कानपुर की एम. एड. की विभिन्न प्रश्नपत्रों की परीक्षा के दौरान छात्रों द्वारा ली गई 'बी' उत्तर पुस्तिकाओं की संख्या को छात्रों के अनुक्रमांक सहित लिख लिया गया। परीक्षाफल घोषित होने के उपरांत छात्रों के विभिन्न प्रश्नपत्रों के प्राप्तांकों को प्राप्त कर लिया गया।

अध्ययनकर्ताओं ने प्रथम परिकल्पना हेतु सांख्यिकीय विश्लेषण के लिए सर्वप्रथम छात्रों द्वारा प्रयुक्त 'बी' उत्तर पुस्तिकाओं की संख्या के आधार पर प्रथम समूह में उन छात्रों को सम्मिलित किया जिन्होंने केवल 'ए' उत्तर पुस्तिका या 'ए' उत्तर पुस्तिका एवं एक 'बी' उत्तर पुस्तिका का प्रयोग किया था। दूसरे समूह में उन छात्रों को रखा गया जिन्होंने एक से अधिक 'बी' उत्तर पुस्तिकाओं का प्रयोग किया था। प्रत्येक प्रश्नपत्र

के लिए उक्त दो समूहों के छात्रों द्वारा प्राप्त अंकों के मध्यमान की गणना की गई तथा दोनों समूहों के मध्यमानों के अंतर की सार्थकता को 'टी' परीक्षण द्वारा परखा गया। सांख्यिकीय विश्लेषण से पूर्व अध्ययन की परिकल्पनाओं को शून्य परिकल्पना में परिवर्तित किया गया।

द्वितीय परिकल्पना हेतु सांख्यिकीय विश्लेषण के लिए प्रथम समूह में उन छात्रों को शामिल किया गया जिन्होंने 5 'ए' उत्तर पुस्तिका तथा 5 'बी' तक उत्तर पुस्तिकाओं का प्रयोग किया। दूसरा समूह उन छात्रों का था जिन्होंने 5 'ए' उत्तर पुस्तिकाओं तथा 5 'बी' उत्तर पुस्तिकाओं से अधिक प्रयोग किया। विश्वविद्यालय की नियमावली के अनुसार प्रत्येक छात्र को 3 अनिवार्य प्रश्नपत्रों तथा 3 में से 2 वैकल्पिक प्रश्नपत्रों को पढ़ना होता है। अतः प्रत्येक छात्र द्वारा प्रयुक्त 'ए' उत्तर पुस्तिकाओं की संख्या 5 है। 'बी' उत्तर पुस्तिकाओं का प्रयोग प्रत्येक छात्र प्रत्येक प्रश्नपत्र में आवश्यकतानुसार कर सकता है। अतः दूसरी परिकल्पना के परीक्षण के लिए 5 'बी' उत्तर पुस्तिकाओं तक प्रयोग करने वाले छात्रों को पहले समूह में तथा 5 'बी' से अधिक उत्तर पुस्तिकाओं का प्रयोग करने वाले छात्रों को दूसरे समूह में रखा गया।

आंकड़ों का विश्लेषण एवं व्याख्या

अध्ययनकर्ताओं ने अध्ययन के परिणामों को अधिक स्पष्ट करने की दृष्टि से प्रत्येक प्रश्नपत्र की अलग-अलग व्याख्या की। तत्पश्चात सभी प्रश्नपत्रों को एक साथ करके भी परिणामों की व्याख्या की।

प्रथम परिकल्पना के परीक्षण हेतु आंकड़ों का विश्लेषण एवं व्याख्या सारणी-1 में दी गई है।

द्वितीय परिकल्पना के परीक्षण हेतु आंकड़ों का विश्लेषण एवं व्याख्या सारणी-2 में दी गई है।

सारणी-1 से स्पष्ट है कि प्रथम प्रश्नपत्र (शिक्षा के दार्शनिक एवं समाजशास्त्रीय आधार) में कम उत्तर पुस्तिकाओं का प्रयोग करने वाले छात्रों का मध्यमान 50.94 तथा अधिक उत्तर पुस्तिकाओं का प्रयोग करने वाले छात्रों का मध्यमान 61.71 है। दोनों समूहों की तुलना करने पर 'टी' का मान 4.13 प्राप्त हुआ है जो कि .01 स्तर पर सार्थक है। अर्थात कम कापी भरने वाले छात्रों की तुलना में अधिक कापी भरने वाले छात्रों ने अधिक अंक प्राप्त किए। द्वितीय प्रश्नपत्र (शिक्षा के मनोवैज्ञानिक आधार) में कम उत्तर पुस्तिकाओं का प्रयोग करने वाले छात्रों का मध्यमान 48.2 तथा अधिक उत्तर पुस्तिकाओं का प्रयोग करने वाले छात्रों का मध्यमान 55.7 है। दोनों समूहों की तुलना हेतु प्राप्त 'टी' का मान 13.88 है जो कि .01 स्तर पर सार्थक है अर्थात दोनों समूहों के प्राप्तांकों में सार्थक अंतर है। दोनों समूहों के मध्यमानों को देखकर यह स्पष्ट है कि कम कापी भरने वाले छात्रों ने कम अंक प्राप्त किए। इसी प्रकार तृतीय प्रश्नपत्र (शैक्षिक अनुसंधान विधियां) के लिए कम और अधिक 'बी' उत्तर पुस्तिकाओं का प्रयोग करने वाले समूहों के बीच 'टी' का मान 1.88 है जो कि एक पुच्छीय परीक्षण के

विभिन्न प्रश्नपत्रों में कम उत्तर पुस्तिकाओं तथा अधिक उत्तर पुस्तिकाओं का प्रयोग करने वाले छात्रों के प्राप्तांकों की तुलना

सारणी-1

प्रश्नपत्र के नाम		संख्या	मध्यमान	मानक त्रुटि	'टी'	सार्थकता स्तर (एक पुच्छीय परीक्षण)
शिक्षा के दार्शनिक एवं समाजशास्त्रीय आधार	ए + 1 बी कापी का प्रयोग करने वाले छात्र ए + 1 बी से अधिक कापी का प्रयोग करने वाले छात्र	18 7	50.94 61.71	2.61	4.13	.01 पर सार्थक
शिक्षा के मनोवैज्ञानिक आधार	ए + 1 बी कापी का प्रयोग करने वाले छात्र ए + 1 बी से अधिक कापी का प्रयोग करने वाले छात्र	18 7	48.2 55.7	0.54	13.88	.01 पर सार्थक
शैक्षिक अनुसंधान की विधियां	ए + 1 बी कापी का प्रयोग करने वाले छात्र ए + 1 बी से अधिक कापियों का प्रयोग करने वाले छात्र	23 2	45.23 63.00	9.46	1.88	.05 पर सार्थक
शैक्षिक प्रशासन एवं वित्त	ए + 1 बी कापी का प्रयोग करने वाले छात्र ए + 1 बी से अधिक कापियों का प्रयोग करने वाले छात्र	10 3	41.00 52.67	4.79	2.44	.05 पर सार्थक
शैक्षिक मापन एवं मूल्यांकन	ए + 1 बी कापी का प्रयोग करने वाले छात्र ए + 1 बी से अधिक कापियों का प्रयोग करने वाले छात्र	8 8	44.63 52.25	3.88	1.96	.05 पर सार्थक
शैक्षिक एवं व्यावसायिक निर्देशन	ए + 1 बी कापी का प्रयोग करने वाले छात्र ए + 1 बी से अधिक कापियों का प्रयोग करने वाले छात्र	9 12	54.56 53.17	2.50	.56	सार्थक नहीं

लिए .05 स्तर पर सार्थक मान 1.68 से अधिक है। अतः यह स्पष्ट होता है कि दोनों समूहों के छात्रों के मध्यमानो में सार्थक अंतर है। सारणी-1 में चतुर्थ प्रश्न पत्र (शैक्षिक प्रशासन एवं वित्त) में दोनों समूहों के मध्यमानों को देखकर यह स्पष्ट होता है कि प्रथम समूह, जिसने कम कापी भरीं उसके औसत प्राप्तांक अधिक कापी भरने वाले समूह के औसत प्राप्तांकों से कम हैं। दोनों समूहों के लिए प्राप्त 'टी' का मान 2.44 है जो कि .05 स्तर पर आवश्यक सार्थक मान 1.76 से अधिक है। इससे यह निष्कर्ष निकलता है कि दोनों समूहों के प्राप्तांकों के मध्य सार्थक अंतर है। पांचवें प्रश्नपत्र (शैक्षिक मापन एवं मूल्यांकन) में प्रथम समूह के छात्रों के प्राप्तांकों का मध्यमान 44.63 है जबकि द्वितीय समूह का मध्यमान 52.25 है। दोनों समूहों के लिए 'टी' का मान 1.96 प्राप्त हुआ जो कि .05 स्तर पर सार्थकता के लिए आवश्यक मान 1.73 से अधिक है। अतः परिणाम से स्पष्ट है कि अधिक कापी भरने वाले तथा कम कापी भरने वाले छात्रों के औसत प्राप्तांकों में सार्थक अंतर है। छठे प्रश्नपत्र (शैक्षिक एवं व्यावसायिक निर्देशन) में 'टी' का मान .56 प्राप्त हुआ जो कि सार्थक नहीं है। अतः यह कहा जा सकता है कि इस प्रश्नपत्र में कम कापी भरने वाले तथा अधिक कापी भरने वाले छात्रों के प्राप्तांकों में सार्थक अंतर नहीं है।

सारणी-2 से यह स्पष्ट है कि सभी प्रश्नपत्रों को एक साथ लेकर कम उत्तर पुस्तिकाएं एवं अधिक उत्तर पुस्तिकाएं प्रयुक्त करने वाले छात्रों के दो समूहों के बीच प्राप्तांकों की तुलना करने पर 'टी' का मान 4.42 प्राप्त हुआ जो कि .01 स्तर पर सार्थक है। इससे स्पष्ट है कि दोनों समूहों के प्राप्तांकों के मध्य सार्थक अंतर है। दोनों समूहों के मध्यमानों पर एक दृष्टि डालने से यह स्पष्ट है कि कम उत्तर पुस्तिकाएं प्रयुक्त करने वाले समूह को कम अंक प्राप्त हुए जबकि जिस समूह ने अधिक उत्तर पुस्तिकाएं प्रयुक्त कीं, उसे अधिक अंक प्राप्त हुए।

सभी प्रश्नपत्रों में एक साथ कम उत्तर पुस्तिकाओं का प्रयोग करने वाले तथा अधिक उत्तर पुस्तिकाओं का प्रयोग करने वाले छात्रों के प्राप्तांकों की तुलना

सारणी-2

	संख्या	*मध्यमान*	*मानक त्रुटि*	*'टी'*	*सार्थकता स्तर (एक पुच्छीय परीक्षण)*
5ए + 5बी कापी प्रयोग करने वाले छात्र	13	231.00	7.96	4.42	.01 स्तर पर सार्थक
5ए + 5बी से अधिक कापी प्रयोग करने वाले छात्र	12	266.17			

निष्कर्ष

सारणी-1 से यह स्पष्ट है कि छह प्रश्नपत्रों में से एक प्रश्नपत्र को छोड़कर अन्य पांचों प्रश्नपत्रों में कम उत्तर पुस्तिका एवं अधिक उत्तर पुस्तिका प्रयुक्त करने वाले छात्रों के दो समूहों के प्राप्तांकों के मध्य सार्थक अंतर है जिससे यह निष्कर्ष निकाला जा सकता है कि अधिक उत्तर पुस्तिका के प्रयोग तथा निष्पत्ति में धनात्मक संबंध है। यदि हम पांचों प्रश्नपत्रों में दोनों समूहों के मध्यमान पर एक दृष्टि डालें तो यह स्पष्ट हो जाता है कि वह समूह जिसने कम कापी भरीं उसके प्राप्तांक कम हैं जबकि जिस समूह ने अधिक कापी भरीं उसके प्राप्तांक अधिक हैं। छह में से पांच प्रश्नपत्रों के परिणामों के आधार पर यह स्पष्ट हो जाता है कि परीक्षा में अधिक उत्तर पुस्तिका का प्रयोग अधिक प्राप्तांकों का परिचायक है। निष्कर्षों की अधिक पुष्टि हेतु अध्ययनकर्ताओं ने सभी प्रश्नपत्रों को एक साथ लेकर दोनों समूहों के प्राप्तांकों के मध्य अंतर जानने का प्रयास किया। सारणी-2 से यह स्पष्ट होता है कि दोनों समूहों के छात्रों के प्राप्तांकों के मध्य सार्थक अंतर है।

प्राप्त परिणाम हमें कुछ सोचने के लिए मजबूर करते हैं। क्या वर्तमान परीक्षाएं अधिक उत्तर पुस्तिकाओं के प्रयोग को प्रेरित कर रही हैं? वर्तमान शिक्षा छात्रों में किस चीज़ को प्रोत्साहित करना चाहती है – लेखन गति या बौद्धिक क्षमता? अध्ययन किए गए छह प्रश्नपत्रों में से तृतीय एवं पंचम प्रश्नपत्र मुख्य रूप से संप्रत्यात्मक, वैज्ञानिक एवं वस्तुनिष्ठ हैं, परंतु इस अध्ययन में इन दोनों प्रश्नपत्रों में भी कम एवं अधिक उत्तर पुस्तिकाएं प्रयुक्त करने वाले छात्रों के प्राप्तांकों के मध्य भी सार्थक अंतर पाया गया। इससे यह निष्कर्ष निकाला जा सकता है कि परीक्षा के समय में जो छात्र जितना अधिक लिख लेता है या जितनी अधिक उत्तर पुस्तिकाओं का प्रयोग करता है उसे उतने ही अधिक अंक प्राप्त होते हैं। यह हमारी वर्तमान परीक्षा प्रणाली की कमियों का एक उदाहरण है। हम सभी जानते हैं कि परीक्षाएं बालक की उपलब्धि का मापन करती हैं। बालक को जिन उद्देश्यों को ध्यान में रखकर पढ़ाया जाता है उनमें से उसने किस सीमा तक उन उद्देश्यों को प्राप्त किया है यह जानने का माध्यम परीक्षाएं होती हैं। परंतु इस अध्ययन के परिणामों से यह सिद्ध हो रहा है कि ऐसा नहीं हो रहा है। आजकल की परीक्षाएं बालक की लेखन गति का मापन कर रही प्रतीत होती हैं, न कि उनकी बौद्धिक क्षमता का। यह कहा जाता है कि उच्च शिक्षा छात्रों में उच्च बौद्धिक क्षमताओं का विकास करती है लेकिन एम. एड. जैसे उच्च शिक्षा स्तर पर ली जाने वाली परीक्षाएं भी अपना उद्देश्य पूरा नहीं कर पा रही हैं।

उपरोक्त परिणाम यह भी स्पष्ट कर रहे हैं कि परीक्षा में प्रायः पूछे जाने वाले विस्तृत उत्तरीय प्रश्न न तो वैध हैं और न ही विश्वसनीय। परीक्षक उत्तर पुस्तिकाओं की जांच करते समय शायद विद्यार्थियों द्वारा लिखे गए उत्तरों को पढ़ने के स्थान पर लिखे गए पृष्ठों को गिनकर अंक दे रहे हैं।

"भारत के भाग्य का निर्माण उसकी कक्षाओं में हो रहा है..." (कोठारी कमीशन, 1968), इस

कथन के आधार पर छात्र हमारी शिक्षा का केंद्र बिंदु हैं। यदि हम उस छात्र का सही मूल्यांकन न कर सकें, तो भविष्य की क्या स्थिति होगी इसकी मात्र कल्पना ही की जा सकती है। अतः मूल्यांकन के बहु प्रचलित साधन 'परीक्षा' में सुधार करना और भी अधिक आवश्यक एवं प्रासंगिक हो गया है।

कुछ सुझाव

प्रस्तुत अध्ययन के परिणामों के आधार पर अध्ययनकर्ताओं ने कुछ सुझाव दिए हैं, जो इस प्रकार हैं :

- ❑ प्रश्नपत्रों के निर्माण में विशेष सावधानी बरती जाए। प्रश्न संप्रत्यात्मक, वैज्ञानिक एवं स्पष्ट हों, जिससे उत्तर देते समय छात्रों को यह पता हो कि उन्हें क्या लिखना है।
- ❑ प्रत्येक प्रश्न के लिए उत्तर देने की सीमा निश्चित कर दी जाए। इससे वह छात्र जो इधर-उधर की बातें लिखकर कापी भरने के प्रयास करते हैं, उन्हें ऐसा करने की आवश्यकता नहीं रहेगी तथा कापी जांचने वाले परीक्षकों को भी अधिक पन्ने पलटने की आवश्यकता नहीं रहेगी।
- ❑ इस अध्ययन से प्राप्त निष्कर्षों की पुष्टि हेतु न्यादर्श का आकार बढ़ाकर पुनः अध्ययन किया जाना चाहिए।
- ❑ एम.एड. के अलावा स्नातक स्तर एवं अन्य स्नातकोत्तर विषयों में भी यह देखा जाए कि क्या उन विषयों में भी अधिक उत्तर पुस्तिकाओं का प्रयोग करने पर अधिक अंक प्राप्त होते हैं। विशेष रूप से विज्ञान एवं वाणिज्य विषयों में यह अध्ययन किया जाना चाहिए। ❑

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शैक्षिक विकास के प्रगतिशील सोपान

रमेश चंद्र पारीक

बी-3 स्टाफ क्वार्टर्स
केंद्रीय विद्यालय परिसर
अलवर 301001

प्रस्तुत अध्ययन 21वीं सदी के आरंभ तक अपने-आपको संपूर्ण साक्षर प्रदेश से गौरवान्वित करने के क्षेत्र में राजस्थान द्वारा किए जा रहे प्रयासों की समग्र जानकारी देता है। शिक्षा के क्षेत्र में राजस्थान सरकार द्वारा वित्तीय बजट, छात्र-छात्राओं की उपस्थिति, प्राथमिक से लेकर उच्च माध्यमिक विद्यालयों तक की संख्यात्मक वृद्धि का तुलनात्मक अध्ययनयुक्त यह लेख अतीत, वर्तमान और भविष्य में तारतम्यता बैठाते हुए उत्तरोत्तर गतिशील विकास को परिलक्षित करता है।

हम आज़ादी की पचासवीं वर्षगांठ 'स्वर्ण जयंती वर्ष' मना चुके हैं तथा सन 2000 तक संपूर्ण साक्षरता अभियान के प्रति कृत संकल्प हैं। शिक्षा के बिना आज़ादी का अहसास अधूरा एवं फीका लगता है, शैक्षिक विकास के बिना सर्वांगीण विकास असंभव है। साक्षर व्यक्ति देश की प्रगति और विकास में सहभागिता करते हैं जबकि निरक्षर व्यक्ति अनेक नवाचारों, नूतन अन्वेषणों व नवीन जानकारी पर कुंडली मार लेते हैं। वे स्वयं की बात हृदय के भावों की अभिव्यक्ति को लिखकर प्रकट नहीं कर पाते, कहीं से आए खत को खुद पढ़ नहीं पाते, ऐसी स्थिति में उनमें हीन भाव विकसित हो जाता है। उनका व्यक्तित्व एवं सर्वांगीण विकास अवरुद्ध हो जाता है। प्रस्तुत लेख में हम राजस्थान के संदर्भ में शैक्षिक विकास एवं उपलब्धियों पर चर्चा करेंगे।

जिस प्रकार निरक्षरता मनुष्य के लिए अभिशाप है उसी प्रकार साक्षरता जीवन वरदान है। केवल अपना नाम लिख लेना या हस्ताक्षर करना सीख लेना साक्षरता की पहली कड़ी हो सकती है किंतु संपूर्ण शिक्षा कदापि नहीं। अक्षर, वर्ण या अंक ज्ञान ही शिक्षा नहीं है। शिक्षा जीवन ज्योति है, खुशहाल दिनचर्या का मधुर संगीत है, समृद्ध परिवार की पहचान है। सुखद जीवन यापन का मनोरम सोपान है। सफलता की कुंजी है, उन्नति व प्रगति का सन्मार्ग है। शिक्षा व्यक्ति के सर्वांगीण विकास की धुरी है जो उसे आत्मनिर्भर, सुयोग्य व स्वावलंबी बनाती है। हम जीवनपर्यंत कुछ न कुछ सीखते रहते हैं। जीवनोपयोगी बातों को अर्जित करते रहते हैं। पठन-पाठन से सक्रिय भाव

से जुड़ना तथा साक्षर नागरिक कहलाना अपने आप में गर्व की बात है।

शैक्षिक विकास की दौड़ में राजस्थान पीछे नहीं है। वह साक्षरता अभियान के माध्यम से 21वीं सदी के आरंभ तक 'संपूर्ण साक्षर प्रदेश' के लक्ष्य को हासिल करने के लिए प्रयत्नशील है। यहां आज़ादी के पश्चात शिक्षा के क्षेत्र में गुणात्मक प्रयास हुए हैं। इसी के फलस्वरूप अजमेर, डूंगरपुर संपूर्ण साक्षर ज़िले घोषित हो पाए हैं। वर्तमान दशक में शैक्षिक विकास एवं उपलब्धियों का सिलसिला सतत बढ़ा है। राजस्थान प्रदेश में शिक्षा के उन्नयन के लिए अनेक सार्थक कदम उठाए गए हैं। यहां राज्य सरकार के अथक प्रयास, शिक्षा विभाग के दृढ़ संकल्प व सुनियोजित प्रबंधन एवं अगाध जन सहभागिता के माध्यम से शिक्षा के सभी क्षेत्रों में, शैक्षिक विकास में आशातीत उपलब्धियां व सफलता हासिल हो रही हैं। किसी भी कार्यक्रम, अभियान को सफल होने के लिए जन सहयोग और धन प्रबंध की आवश्यकता होती है। शिक्षा बजट में इसी ध्येय की प्राप्ति के लिए उल्लेखनीय वृद्धि की गई है :

तालिका-1 से यह स्पष्ट है कि शिक्षा के विकास के लिए राज्य सरकार पर्याप्त धन उपलब्ध करा रही है, शिक्षा के क्षेत्र में भागीरथी प्रयासों में तल्लीन है।

शिक्षा जीवन का सुघड़ आलोक है। शिक्षा के माध्यम से ज्ञान रश्मियां मन में अज्ञान रूपी अंधकार को हटा देती है, नूतन उमंग के साथ सुबह की सुहानी भोर का अहसास कराती हैं। 'आखर धुन', साक्षर बनने की उत्कंठा व लगन और अक्षर भिन्न कहलाने का गौरव मन को उल्लसित कर देता है। शैक्षिक विकास की पुनीत कामना से सराबोर राजस्थान प्राथमिक शिक्षा के सार्वजनीकरण पर सदैव बल देता रहा है। विद्यालयों में नामांकन वृद्धि के लिए प्रत्यक्ष भाव से प्रयत्नशील रहा है। विगत चार वर्षों में 6 से 14 वर्ष तक की आयु वर्ग के विद्यार्थियों की संख्या में (लगभग 18 लाख) वृद्धि हुई है जो शिक्षा के क्षेत्र में किए जा रहे सार्थक व सक्रिय प्रयासों को उजागर करती है। आइए विद्यार्थियों की संख्या पर दृष्टिपात करें :

तालिका-1

बजट की तुलनात्मक स्थिति

बजट मद	*प्रावधानिक राशि (करोड़ रु. में)*		*वृद्धि (%)*
	1993-94	*1997-98*	
केंद्रीय प्रवर्तित	35.85	88.29	146.3
आयोजना	125.90	187.65	49.0
आयोजना भिन्न	811.62	2078.00	156.0
योग	973.37	2353.94	141.8

तालिका-2

विद्यार्थियों की संख्या

वर्ष	विद्यार्थियों की संख्या (लाखों में)		
	बालक/छात्र	छात्रा/बालिका	योग
1993	53.28	23.70	76.98
1997	61.71	33.18	94.89
वृद्धि	8.43	9.48	17.91

विद्यार्थियों की संख्या में गुणात्मक अभिवृद्धि नए विद्यालय खोलने, आनंदमयी शिक्षण पद्धति अपनाने, नामांकन वृद्धि का लक्ष्य निर्धारित करने, प्रवेशोत्सव आयोजित करने, ठहराव अभियान के लिए अभिभावकों को प्रेरित करने एवं उनका सहयोग लेने और अनेक साक्षरता कार्यक्रमों को क्रियान्वित करने से उत्तरोत्तर कीर्तिमान बन पाए हैं। प्रवेश में पहली जुलाई से शाला प्रवेशोत्सव पखवाड़ा हर्षोल्लास से मनाया गया, बालकों को विद्यालय से जोड़ा गया। नामांकन और ठहराव पर बल दिया गया। इससे अपव्यय और अवरोध कम हुआ, उत्साहजनक परिणाम सामने आए। बालकों को प्राथमिक शिक्षा उपलब्ध कराना हम सभी का पुनीत दायित्व है। हमें यह देखना है कि 6 से 14 वर्ष तक के आयुवर्ग के समस्त बालक-बालिकाओं का विद्यालय में नामांकन सुनिश्चित हो तथा अभिभावकों को प्रेरित करके, बालकों में शिक्षा के प्रति आकर्षण पैदा करें, अध्यापकों की पर्याप्त नियुक्ति करें, ठहराव युक्त नामांकन और गुणवत्ता पूर्ण शिक्षा को हासिल किया जाए।

शाला प्रवेशोत्सव कार्यक्रम अक्षर मित्र पुरस्कार से जन भागीदारी में अभिवृद्धि हुई है, नागरिकों व अभिभावकों के रुझान व सहयोग में बदलाव आया है। प्रत्येक गांव में ग्राम साक्षरता समिति, ज़िला स्तर पर ज़िला साक्षरता समिति का गठन किया गया है जो शिक्षा के क्षेत्र में अविरल प्रगति का सर्वे एवं मूल्यांकन करती है, समीक्षा प्रस्तुत करती है।

साथ ही अभिभावकों से संपर्क कर उनसे संवाद व समीक्षा करती है। शिक्षा के क्षेत्र में उत्कृष्ट योगदान के लिए ग्राम पंचायत, तहसील, ज़िला, संभाग व राज्य स्तर पर अनेक प्रकार के प्रशस्ति पत्र, प्रोत्साहन पुरस्कारों की श्रेष्ठ शृंखला संचालित है जो इस क्षेत्र से जुड़े लोगों को सम्मान प्रदान करती है, उनकी रुचि-अभिरुचि, कार्य पद्धति को जागृत करती है।

यहां प्रत्येक बालक-बालिका को शिक्षा उपलब्ध कराने के क्षेत्र में, संपूर्ण साक्षरता अभियान के क्रियान्वयन में शिक्षा कर्मी योजना, गुरु मित्र योजना, लोक जुंबिश परियोजना, डी.पी.ई.पी., आखर धाम, प्रहरी व दिवस पाठशालाएं, सरस्वती योजना, अनौपचारिक शिक्षा केंद्र इत्यादि सार्थक एवं समाजोपयोगी भूमिका निभा रहे हैं। सभी कार्यक्रम व योजनाएं साक्षरता को सकारात्मक पहलू से,

रोचक गतिविधि से तथा आनंदमयी शिक्षण पद्धति से सफल बनाने में तल्लीन है। इससे शिक्षा में संख्यात्मक एवं गुणात्मक दृष्टिकोण से सुधार हुआ है। विद्यालयों में छात्रों के नामांकन व ठहराव में सराहनीय वृद्धि हुई है। असीम जन सहभागिता ने इसमें चार चांद लगा दिए हैं। यदि शैक्षिक विकास के प्रगतिशील सोपानों की विकासधारा इसी भावना व प्रयास से प्रवाहित होती रही तो हम सहज ही 21वीं सदी का स्वागत 'संपूर्ण साक्षर' भाव से करेंगे।

जिस प्रकार शिक्षा सर्वाधिक फलदायी वरदान है उसी प्रकार अशिक्षा सबसे भीषण अभिशाप है, कलंक है। कोई भी समझदार व्यक्ति अज्ञान व अशिक्षा के कलंक को सहन नहीं कर पाएगा। शिक्षा से बढ़कर कोई मान, सम्मान, स्वाभिमान व दान नहीं है। शिक्षा के क्रमिक विकास के क्षेत्र में राजस्थान प्रदेश में अनेक भागीरथी प्रयास किए गए हैं। सातवीं पंचवर्षीय योजना में जहां 28 करोड़ रुपये व्यय किए गए वहां आठवीं पंचवर्षीय योजना में 1039 करोड़ रुपये व्यय हुए। प्राथमिक शिक्षा को बढ़ावा देने के लिए विगत चार वर्षों में राजकीय विद्यालयों में अध्ययन कर रही कक्षा 1 से 8 तक की बालिकाओं तथा कक्षा 1 से 5 तक के बालकों को पाठ्यपुस्तकें निःशुल्क वितरित की जा रही हैं जिससे 217.80 लाख छात्र-छात्राओं को लाभ पहुंचा है तथा इसमें अब तक 52.30 करोड़ रुपया खर्च हो चुका है। आठवीं पंचवर्षीय योजना में 5730 प्राथमिक तथा 2649 उच्च विद्यालय खोले गए हैं। राज्य सरकार ने सामान्य क्षेत्र के 250 की जनसंख्या वाले हरेक गांव तथा जनजाति एवं मरुस्थलीय क्षेत्र के 150 की आबादी वाले प्रत्येक राजस्व ग्राम में दो शिक्षकों वाला प्राथमिक विद्यालय उपलब्ध करवाया है। प्रत्येक पंचायत क्षेत्र में एक उच्च प्राथमिक विद्यालय खोला गया है। विद्यालयों की संख्या में की गई अप्रत्याशित वृद्धि को तालिका-3 के माध्यम से समझ सकते हैं :

तालिका - 3

समस्त विद्यालयों की संख्या

वर्ष	*1993*			*1997*			*वृद्धि*	
विद्यालय	*राजकीय*	*मान्यता प्राप्त*	*योग*	*राजकीय*	*मान्यता प्राप्त*	*योग*	*वृद्धि*	*प्रतिशत*
प्राथमिक	30056	3031	33087	31663	2373	34036	949	2.9
उच्च प्राथमिक	8072	1781	9853	10553	3110	13663	3810	38.7
माध्यमिक	2894	442	3336	2983	651	3634	298	8.9
उच्च माध्यमिक	804	284	1088	1143	348	1491	403	37
कुल योग	41826	5538	47364	46342	6482	52824		

राजस्थान में शैक्षिक विकास एवं उन्नयन के क्षेत्र में अनेक कार्यक्रम, योजनाएं क्रियान्वित हैं। इस समय 16 परियोजनाओं के तहत 210 पंचायत समितियों में अनौपचारिक शिक्षा केंद्र संचालित किए जा रहे हैं। लोक जुंबिश परियोजना के तहत 1237 सहज शिक्षा केंद्र तथा शिक्षाकर्मी परियोजना के तहत 3520 प्रहर पाठशालाएं संचालित की जा रही हैं। वर्ष 1996-97 में अनौपचारिक शिक्षा कार्यक्रम के संचालन के लिए 22 करोड़ रुपये का प्रावधान किया गया था। वर्तमान में यह राज्य के 32 जिलों में अलग-अलग चरणों में चलाया जा रहा है। इस अभियान का लक्ष्य राज्य के 15 से 35 वर्ष के आयुवर्ग के लगभग 90 लाख निरक्षरों को साक्षर करना है। प्राथमिक शिक्षा के सार्वजनीकरण के लक्ष्य को प्राप्त करने में अनौपचारिक शिक्षा बहुत महत्वपूर्ण भूमिका निभा रही है।

वर्ष 1975 में मात्र 230 केंद्रों से प्रारंभ किए गए अनौपचारिक शिक्षा कार्यक्रम के तहत अब (1997-98) 17600 अनौपचारिक शिक्षा केंद्र हो गए हैं। इन केंद्रों के माध्यम से 5 लाख बच्चों को शिक्षा दी जा रही है जिनमें 60% बालिकाएं शामिल हैं। ये अनौपचारिक शिक्षा केंद्र स्थानीय बालकों की सुविधा के अनुसार ग्रामवासियों के सक्रिय सहयोग से संचालित किए जा रहे हैं। इसे शिक्षा के विकास में एक क्रांतिकारी कदम माना जा सकता है। स्वाधीनता के समय साक्षरता की दृष्टि से राजस्थान की स्थिति बहुत कमज़ोर व दयनीय थी जिसमें महिला शिक्षा की स्थिति अत्यंत शोचनीय थी। यहां बालिका का जन्म ही अशुभ माना जाता था। ऐसे अंधविश्वासों व कुरीतियों की गर्त में दबे समाज से बालिका शिक्षा की बात दिवास्वप्न थी। किंतु आज़ादी के बाद शिक्षा के क्षेत्र में अनुकूल परिणाम सामने आए हैं। इसमें सरकारी प्रयास व जनता की सहभागिता प्रशंसनीय है।

माध्यमिक शिक्षा बोर्ड की परीक्षा के परिणामों में उत्तरोत्तर वृद्धि हुई है। परीक्षा परिणाम को शत-प्रतिशत बनाने के लिए विद्यालय स्तर पर अनेक प्रशंसनीय कदम उठाए गए हैं। प्री-बोर्ड परीक्षा का आयोजन, शैक्षिक सुविधाओं व वेतनमानों में वृद्धि, प्रोन्नतियों में वृद्धि पाक्षिक व मासिक मूल्यांकन योजना, शिक्षकों का व्यावसायिक उन्नयन, खेलकूद प्रतिस्पर्धाओं का आयोजन, विद्यालय स्तरीय सह शैक्षिक गतिविधियों का सफल क्रियान्वयन, छात्रों के अभिभावकों से निरंतर संपर्क रखकर उनके अध्ययन की जानकारी देना। शिक्षकों द्वारा निष्ठापूर्वक अध्यापन सतत गृहकार्य की जांच, पुस्तकालय, वाचनालय व शिक्षण सामग्री का अधिकतम प्रयोग, प्रार्थना सभा में प्रेरक प्रसंगों की प्रस्तुति, उपचारात्मक कक्षाएं, कमज़ोर व ज़रूरतमंद छात्रों को समुचित मार्गदर्शन इत्यादि आयामों के माध्यम से संख्यात्मक एवं गुणात्मक रूप से परीक्षा परिणाम में निरंतर अभिवृद्धि हुई है जो शैक्षिक उत्कृष्टता को प्रतिबिंबित करती है। यहां बोर्ड परीक्षा परिणामों पर केंद्रित तालिका प्रस्तुत है:

राजस्थान में शैक्षिक विकास को प्रगतिशील बनाए रखने के उद्देश्य से अनेक योजनाएं लागू की गई हैं। राज्य के पिछड़े, दुर्गम एवं शिक्षा से

तालिका-4

बोर्ड परीक्षा परिणामों में मात्रात्मक एवं गुणात्मक सुधार
अ—माध्यमिक परीक्षा परिणाम (प्रतिशत में)

वर्ष	*श्रेणी*		
	प्रथम	*द्वितीय*	*तृतीय*
1993	12.2	33.3	54.5
1997	18.1	39.4	42.5

ब—उच्च माध्यमिक परीक्षा परिणाम (प्रतिशत में)

संकाय	*कला*			*विज्ञान*			*वाणिज्य*		
श्रेणी	*प्रथम*	*द्वितीय*	*तृतीय*	*प्रथम*	*द्वितीय*	*तृतीय*	*प्रथम*	*द्वितीय*	*तृतीय*
वर्ष									
1993	3.5	37.3	59.2	18.1	63.7	18.2	10.6	40.9	48.5
1997	11.2	53.3	35.5	37.0	60.0	3.0	21.4	49.8	28.8

वंचित क्षेत्रों में प्राथमिक शिक्षा की सुविधा उपलब्ध कराने के लिए सीड़ा और राज्य सरकार के वित्तीय सहयोग से शिक्षाकर्मी परियोजना राज्य के 32 में से 29 ज़िलों की 128 पंचायत समितियों के 2145 ग्रामीण विद्यालयों में 4823 शिक्षाकर्मियों द्वारा संचालित है। साथ ही 3474 प्रहर पाठशालाएं भी चल रही हैं। लोक जुंबिश, जन उत्प्रेरणा एवं जन सहभागिता से प्राथमिक शिक्षा के सार्वजनीकरण एवं शिक्षा के गुणात्मक सुधार की उपयोगी परियोजना है जो 75 विकास खंडों में संचालित है तथा राज्य के 13 ज़िले लोक जुंबिश परियोजना के अंतर्गत चयनित हैं। ज़िला प्राथमिक शिक्षा परियोजना (डी.पी.ई.पी.) हेतु शेष चयनित 19 ज़िलों के 18 विकास खंडों में पहले से लोक जुंबिश चल रही है। इस समय समस्त 32 ज़िलों में साक्षरता अभियान प्रगति पर है। राज्य का अजमेर ज़िला साक्षरता अभियान के तृतीय चरण में, 12 ज़िले उत्तर साक्षरता चरण में, जबकि शेष 20 में से 19 ज़िलों में (जेसलमेर को छोड़कर) पठन पाठन कार्य प्रगति पर है।

राजस्थान में वर्ष 1996-97 में कुल ग्यारह लाख व्यक्ति नवसाक्षर हुए। अब तक 23.87 लाख लोगों को नवसाक्षर बनाया जा चुका है। गुरु मित्र योजना एक प्रकार से प्राथमिक शिक्षा के लिए नवाचार है। यह अब तक 10 ज़िलों में लागू की गई है। इसके अलावा प्रोत्साहन व सम्मान योजना भी कारगर साबित हो रही है। प्रतिवर्ष 5 सितंबर को शिक्षक दिवस पर शिक्षक सम्मान

समारोह, 28 जून को भामाशाह सम्मान समारोह, 12 जनवरी को श्रेष्ठ परीक्षा परिणाम पर संस्था प्रधानों को संदीपन पुरस्कार, राजकीय विद्यालय सम्मान समारोह, बोर्ड परीक्षा में उत्कृष्ट परिणाम देने वाली प्रतिभावान छात्राओं को गार्गी पुरस्कार दिए जाते हैं। मध्याह्न भोजन, पोषाहार कार्यक्रम विद्यार्थी सुरक्षा बीमा योजना, अनुसूचित जाति, जनजाति व निर्धन वर्ग के बच्चों को निःशुल्क शिक्षा, विभागीय पदोन्नतियों में अभूतपूर्व वृद्धि, बालिका शिक्षा का विस्तार आदि पहलुओं से शैक्षिक उपलब्धियों में चार चांद लग गए हैं। शैक्षिक विकास के प्रगतिशील सोपानों का यह सिलसिला अविरल उत्तरोत्तर स्वरूप में चलता रहे, साक्षरता की ज्योति देदीप्यमान रहे। ❑

उच्च शिक्षा में गुणात्मक सुधार

अमरनाथ दत्त गिरि

प्रवक्ता, शिक्षक शिक्षा विभाग
अतर्रा पी.जी. कालेज, अतर्रा
बांदा, उत्तर प्रदेश

स्वतंत्रता प्राप्ति के बाद भारत में उच्च शिक्षा का बड़ी तेज़ी से संख्यात्मक विस्तार हुआ है। वर्तमान में लगभग 220 विश्वविद्यालय, 8000 कालेज और इनमें पंजीकृत 60 लाख छात्र इस तथ्य की पुष्टि करते हैं। इसके बावजूद विश्वविद्यालय व कालेज हमारे उन अधिसंख्य छात्रों को प्रवेश देने में असमर्थ हैं जो उच्च शिक्षा के आकांक्षी हैं। एक तरफ जहां आश्चर्यजनक संख्यात्मक विस्तार हुआ है वहीं हम इसकी गुणवत्ता को बनाए रखने में विफल हुए हैं। यद्यपि विभिन्न शिक्षा आयोगों ने उच्च शिक्षा के क्षेत्र में गुणात्मक सुधार हेतु कई अनुशंसाएं की थीं तथापि इच्छाशक्ति के अभाव में उन पर समुचित ध्यान नहीं दिया गया। यदि हमें नई चुनौतियों का सामना करना है तो उच्च शिक्षा की गुणवत्ता बनाए रखने वाले उपायों को तत्काल क्रियान्वित करना होगा।

शिक्षा का सामाजिक विकास में महत्वपूर्ण योगदान होता है, इस तथ्य को भारतीय योजनाकारों और नीति-निर्माताओं ने भली-भांति स्वीकार किया है। शिक्षा में सुधारों का इतिहास और साथ में इस बारे में जारी बहस इस बात का प्रमाण है। यदि हम अपने तात्कालिक अतीत पर एक दृष्टि डालें तो पाते हैं कि हमें 1968 की राष्ट्रीय शिक्षा नीति विरासत में मिली है, शिक्षा के इतिहास में इस नीति की महत्वपूर्ण भूमिका रही है।

1968 की शिक्षा नीति में ये लक्ष्य रखे गए थे — 'राष्ट्रीय प्रगति, समान नागरिकता और समान संस्कृति की भावना को बढ़ावा देना तथा राष्ट्रीय एकता को मज़बूती प्रदान करना। इसमें शिक्षा प्रणाली के राष्ट्रीय पुनर्निर्माण की आवश्यकता, सभी स्तरों पर शिक्षा की गुणवत्ता में सुधार, तथा विज्ञान और टेक्नोलाजी पर अधिक ध्यान देने पर बल दिया गया। शिक्षा में नैतिक मूल्यों को शामिल करने और शिक्षा को लोगों के जीवन से संबद्ध बनाने की आवश्यकता पर भी ज़ोर दिया गया।' (यूनिवर्सिटी न्यूज़ : 1986)

स्वतंत्रता प्राप्ति के पश्चात भारत में उच्च शिक्षा का बड़ी तेज़ी से संख्यात्मक विकास हुआ है। उच्च शिक्षा के क्षेत्र में हुई वृद्धि का सही अनुमान लगाने के लिए यह आवश्यक है कि ब्रिटिशकालीन शिक्षा के स्वरूप पर दृष्टिपात किया जाए। सन 1947 तक कालेजों एवं विश्वविद्यालयों में पढ़ने वाले छात्रों की संख्या कुछ हज़ारों में थी जबकि आज यह लाखों में है। छात्रों की वर्तमान संख्या लगभग 60 लाख है और सन 2010 तक

उसके एक करोड़ हो जाने का अनुमान है। विश्वविद्यालयों की कुल संख्या सन 1947 में 20 थी जो आज ग्यारह गुना अधिक अर्थात 220 (प्रस्तावित विश्वविद्यालयों सहित) हो गई है। अन्य किसी देश में वृद्धि इस पैमाने पर नहीं हुई है। इसके बावजूद आज की जनसंख्या वृद्धि की दर तथा वर्तमान शिक्षा प्रणाली को देखते हुए भारत में 1000 विश्वविद्यालयों और एक लाख कालेजों (8000 के स्थान पर) की आवश्यकता है। यहां उच्च शिक्षा में संलग्न छात्रों की संख्या स्वीडन, स्विटज़रलैंड अथवा नीदरलैंड की कुल जनसंख्या से अधिक है।

यद्यपि उच्च शिक्षा का यह संख्यात्मक विकास बहुत आश्चर्यजनक है तथापि सर्वत्र यह चिंता और चर्चा का विषय रहा है कि शिक्षा के सभी स्तरों पर गुणात्मक सुधार के स्थान पर निरंतर गिरावट के दर्शन हो रहे हैं। विभिन्न शिक्षा आयोगों और उनके सुझावों के बावजूद स्वतंत्र भारत में उपनिवेशवादी शिक्षा का प्रचलन जारी है। राधा-कृष्णन् कमीशन, कोठारी कमीशन, आदिशेषय्या कमीशन, पुन्नय्या कमीशन, एवं विभिन्न यू.जी.सी. कमेटियों एवं कार्यदलों द्वारा दिए गए सुझावों पर अमल करके उच्च शिक्षा का स्तर सुधारा जा सकता था। दुर्भाग्य से इन पर अमल नहीं किया गया यद्यपि नई कमेटियों और नए आयोगों का क्रम जारी रहा। कोई संरचनात्मक बदलाव नहीं लाया गया जिसके कारण आज भी वर्षों पुरानी शिक्षा पद्धति बिना किसी विशिष्ट बदलाव के जारी है।

राष्ट्रीय शिक्षा नीति (1986) में उच्च शिक्षा के क्षेत्र में गुणात्मक दृष्टि से आती जा रही कमी को गंभीरता से लिया गया है। साथ ही गुणवत्ता में सुधार लाने हेतु गंभीरता से सोचा जा रहा है। पाठ्यक्रम में सुधार, नई शिक्षा पद्धतियां, विश्वविद्यालय नेतृत्व, कार्यक्रम तकनीकीगत उपायों को उन्नत बनाने का प्रावधान, आदि इसी सोच का परिणाम है। उच्च शिक्षा के विकेंद्रीकरण और अवसरों की वृद्धि के लिए मुक्त विश्वविद्यालय की स्थापना भी की गई है। फिर भी बहुत कुछ करना शेष है।

कुछ अनुत्तरित प्रश्न

वास्तविकता यह है कि उच्च शिक्षा के इच्छुक सभी छात्रों को हम उच्च शिक्षा प्रदान करने की स्थिति में नहीं हैं। एक तो संरचनात्मक सुविधाएं ही पर्याप्त नहीं हैं, दूसरे जो सुविधाएं हैं भी उनका सामाजिक, राजनीतिक, आर्थिक एवं सांस्कृतिक कारणों से पूर्ण उपयोग नहीं हो पाता। केरल विश्वविद्यालय के पूर्व उपकुलपति डा. जे.वी. विलानिलम ने कुछ प्रमुख प्रश्न उठाए हैं, जिनका उत्तर अभी नहीं दिया जा सका है। उनमें से कुछ इस प्रकार हैं :

1. क्या वर्तमान में दी जा रही उच्च शिक्षा देश की आवश्यकताओं को पूरा करने में सक्षम है?
2. क्या हाईस्कूल पास प्रत्येक विद्यार्थी के लिए उच्च शिक्षा प्राप्त करना अनिवार्य है?
3. क्या नौकरी के लिए उच्च शिक्षा की डिग्री आवश्यक है? नौकरी को डिग्री से पृथक किया जा सकता है अथवा नहीं?
4. क्या उच्च शिक्षा प्राप्त सभी व्यक्तियों को उचित रोज़गार मिल पाता है? यदि नहीं, तो

क्या उच्च शिक्षा के उद्देश्य और पाठ्यक्रम में बदलाव नहीं किया जाना चाहिए?

5. क्या यह आवश्यक नहीं कि पाठ्यक्रमों का ढांचा और स्वरूप तथा साथ ही उनके चुनाव की पद्धति को पूर्णतः बदला जाए? क्या युवा छात्रों के वैयक्तिक उद्देश्यों एवं रुचियों के अनुरूप पाठ्यक्रम के चुनाव में लचीलापन नहीं होना चाहिए? क्या यह संभव नहीं कि युवा एंव प्रौढ़ छात्र अपनी गति से चलते हुए उच्च शिक्षा प्राप्त करें ताकि वे अपनी ज़रूरी आर्थिक ज़िम्मेदारियों से निपटने के पश्चात ही उच्च शिक्षा हासिल कर सकें?
6. क्या ऐसे तकनीकी एवं व्यवसायमूलक पाठ्यक्रम और नहीं बढ़ाए जा सकते जो न केवल रोज़गार प्राप्ति में, अपितु अपना स्वयं का काम-धंधा शुरू करने में विद्यार्थियों के लिए सहायक हों?
7. क्या राष्ट्रीय एकता एवं राष्ट्रीय विकास की दृष्टि से उच्च शिक्षा का स्वरूप बदला जाना आवश्यक है?
8. क्या प्रत्येक कालेज एवं विश्वविद्यालय में लाइब्रेरी, पठन-कक्ष, प्रयोगशाला, कंप्यूटर नेटवर्क, एंव भौतिक शिक्षा (हर विद्यार्थी के लिए अनिवार्य) की सुविधाएं विद्यमान हैं)?
9. क्या कालेजों के विश्वविद्यालयों में संबंद्धीकरण की वर्तमान पद्धति में बदलाव आवश्यक है ताकि वे प्रशासन, शिक्षण, पाठ्यक्रम के संयोजन एवं मूल्यांकन आदि में अधिक स्वायत्तता बरत सकें? क्या कालेज अथवा विश्वविद्यालयों के प्रबंध में शिक्षण, प्रशासन एवं आर्थिक मामलों के विकेंद्रीकरण का सिद्धांत अधिक प्रभावी नहीं बनाया जा सकता?
10. कालेजों एवं विश्वविद्यालयों से दी जाने वाली शिक्षा को समाज और देश की सामाजिक-आर्थिक एवं विकास-संबंधी समस्याओं के समाधान में अधिक सार्थक बनाने के लिए हम क्या कर सकते हैं? विश्वविद्यालयों का उद्योग, स्थानीय प्रशासन एवं स्थानीय जनता से संबंध मज़बूत करने और उनमें आपसी विचार-विनिमय प्रभावी बनाने के लिए क्या कदम उठाए जाएं?
11. क्या शिक्षा प्रणाली को अधिक उदार एवं अनौपचारिक नहीं बनाया जा सकता ताकि नए कालेजों की स्थापना का आर्थिक बोझ कम किया जा सके?
12. क्या विश्वविद्यालय वास्तव में विद्वत्ता एवं नेतृत्व के विकास के केंद्र बन सकते हैं ताकि देश को हर प्रकार का लाभ हो और महिलाओं तथा जनसंख्या के सुविधावंचित वर्गों को अधिकार संपन्न बनाया जा सके जिसके बिना देश की स्थिति में वास्तविक सुधार संभव नहीं है?
13. ग्रामीण क्षेत्रों में स्वास्थ्य, स्वच्छता, पर्यावरण, खाद्य संरक्षण, शिक्षा, रोज़गार, सड़क परिवहन, खेलकूद एवं सांस्कृतिक मनोरंजन, जल वितरण, परिवहन एवं संचार आदि के क्षेत्र में जीवन स्तर सुधारने में शिक्षा का क्या योगदान हो सकता है? क्या उच्च शिक्षा ग्रामीण परिवेश में सार्थक है?
14. उपर्युक्त प्रश्नों से जुड़ी सब समस्याओं के

समाधान में सूचना एवं संचार की कंप्यूटरीकृत एवं संबद्ध प्रणालियां कहां तक उपयोगी सिद्ध हो सकती हैं?

15. क्या विभिन्न विश्वविद्यालयी संगठनों/इकाइयों के पुनर्गठन की आवश्यकता है ताकि वे अधिक व्यवस्थित ढंग से कार्य कर सकें और उनमें विद्वत्ता का स्तर ऊपर उठ सके?

इन प्रश्नों का उत्तर देकर ही वर्तमान शिक्षा सुविधाओं का पूर्ण लाभ उठाया जा सकता है और देश की प्रगति के लिए नई और प्रभावी सुविधाएं जुटाई जा सकती हैं।

उच्च शिक्षा का लक्ष्य अभी दूर

कोठारी कमीशन (1968) ने उच्च शिक्षा में गुणात्मक सुधार लाने और उसे समाज तथा अर्थव्यवस्था को अन्य क्षेत्रों से जोड़ने की आवश्यकता पर अत्यधिक बल दिया था। नई शिक्षा नीति (1986) के दस्तावेज़ 'शिक्षा की चुनौतियां : नीतिगत परिदृश्य' में इसी आधार पर उच्च शिक्षा के माध्यम से गुणवत्ता लाने व चरित्र-निर्माण पर विशेष बल दिया गया। नीति में सांस्कृतिक आयामों तथा भारतीय समाज के बहु-सामुदायिक स्वरूप पर भी बल दिया गया है। नई शिक्षा नीति में यह ध्यान रखा गया है कि औपचारिक शिक्षा और देश की समृद्ध एवं विविध सांस्कृतिक परंपराओं के बीच गहरा अंतराल है। इसमें ज़ोर देकर कहा गया है कि आधुनिक टेक्नोलाजी के नाम पर नई पीढ़ियों को भारतीय इतिहास और संस्कृति की जड़ों से दूर नहीं किया जा सकता। बहुत पहले रवींद्रनाथ टैगोर ने ऐसे ही विचार व्यक्त किए थे – "शिक्षा का सर्वोत्कृष्ट उद्देश्य हमें इस तथ्य की जानकारी देता है कि संपूर्ण ज्ञान और हमारी सभी सामाजिक तथा आध्यात्मिक गतिविधियों के बीच आंतरिक एकता है।"

क्या हम इस लक्ष्य की ओर बढ़ रहे हैं? क्या हमने छात्रों, नागरिकों के व्यक्तित्व निर्माण में उच्च शिक्षा के स्वरूप और विषय वस्तु का गंभीरतापूर्वक परीक्षण कर लिया है? जयप्रकाश नारायण ने बहुत पहले 1978 में ही औपचारिक शिक्षा की उपलब्धियों से निराश होकर कहा था, "दुर्भाग्य से अपने लिए हमने शिक्षा की जो औपचारिक पद्धति चुनी है वह व्यक्तित्व विकास और सामाजिक परिवर्तन, दोनों ही कार्यों को पूरा करने में विफल रही है। यह उच्च और मध्य वर्गों को गलत शिक्षा देती है, जो इसके प्रमुख लाभार्थी हैं। यह उन्हें अपनी ही संस्कृति का दुश्मन बना रही है क्योंकि इससे वे उपभोक्तावादी औद्योगिक समाज के मूल्यों और जीवन शैलियों को अपनाते जा रहे हैं। यह उन्हें परजीवी वर्ग में परिवर्तित कर रही है, जिससे अधिकाधिक संख्या में लोग निर्धनता की जकड़ में फंसते जा रहे हैं..." (सिटीज़न फॉर डेमोक्रेसी : 1978)।

गुणात्मक सुधार : कुछ सुझाव

उच्च शिक्षा के तीन स्तर हैं – स्नातक स्तर, स्नातकोत्तर स्तर और शोध स्तर। इन तीनों स्तरों पर एक साथ प्रभावी उपाय करने होंगे, यद्यपि

पहले से ही काफी उपाय किए गए हैं किंतु दृढ़ इच्छाशक्ति व प्रतिबद्धता के अभाव में उनसे अपेक्षित परिणाम प्राप्त नहीं हुए हैं। कुछ सुझाव इस प्रकार हैं :

❑ **प्रवेश पर नियंत्रण :** हम जानते हैं कि कमज़ोर नींव पर बना भवन टिकाऊ नहीं हो सकता। उसी प्रकार स्नातक, स्नातकोत्तर और शोध स्तर पर प्रवेश के मानक बहुत कड़े होने चाहिए। प्रवेश परीक्षाएं ईमानदारी से कराई जाएं और बैकडोर से प्रवेश किसी भी तरह संभव न हो। ऐसा करने से वही छात्र प्रवेश पा सकेंगे जिनमें संबंधित पाठ्यक्रम को सीखने व आत्मसात करने की अभिक्षमता (एप्टीट्यूड) होगी। साधन व सुविधाओं को ध्यान में रखकर उच्च शिक्षा में सीमित संख्या में ही प्रवेश दिया जाए।

❑ **शोध कार्य हेतु कड़े प्रावधान :** विश्वविद्यालयों को छोड़कर अन्य संबद्ध कालेजों में छात्रों द्वारा शोध कार्य करने पर प्रतिबंध लगा देना चाहिए। कारण इन कालेजों में शोध कार्य की बुनियादी सुविधाओं यथा, पुस्तकालय, शोध पत्रिकाएं, एनसाइक्लोपीडिया, फोटो स्टेट मशीन, संबंधित उपकरण आदि का प्रायः अभाव रहता है। हालांकि कुछ ख्याति प्राप्त कालेजों में उक्त सुविधाएं उपलब्ध हैं। विश्वविद्यालय अनुदान आयोग द्वारा ली जाने वाली 'नेट' जैसी परीक्षाओं के माध्यम से ही योग्यता प्राप्त छात्रों को पी-एच.डी. अथवा शोध कार्य की अनुमति प्रदान की जानी चाहिए। शोध कार्य कराने वाले निर्देशक की पात्रता/विशेषज्ञता का निर्धारण एक विशेषज्ञ समिति द्वारा किया जाना चाहिए। इधर-उधर से उड़ाकर अथवा हेरा-फेरी से काल्पनिक शोध कार्य करने वालों के खिलाफ कड़ी कार्रवाई की जाए।

❑ **शिक्षकों की नियुक्ति व प्रमोशन :** शिक्षा के प्रत्येक स्तर पर शिक्षक की भूमिका महत्वपूर्ण होती है, विशेष रूप से उच्च शिक्षा के स्तर पर। अतः शिक्षकों की नियुक्ति पर विशेष ध्यान देना होगा। कौन नहीं जानता कि नियुक्तियों में 'अपने लोगों' को नियुक्त कराने के लिए निम्न से निम्नतर भ्रष्ट उपायों का सहारा लिया जाता है। देश की कुछ ख्याति प्राप्त शिक्षण संस्थाओं को छोड़कर अधिकतर संस्थाओं में शिक्षकों का एक बड़ा भाग ऐसा है जिनमें शिक्षण और शोध की अभिक्षमता (एप्टीट्यूड) नहीं है। और तो और उनका विषय ज्ञान भी इस लायक नहीं है कि वे डिग्री स्तर की कक्षाएं पढ़ा सकें। (यदि शिक्षकों की योग्यता/सक्षमता का सर्वेक्षण/परीक्षण किया जा सके तो वास्तविकता सामने आ जाएगी। इस हेतु :

(1) शिक्षकों की नियुक्ति 'नेट' परीक्षा, साक्षात्कार और कक्षा में प्रत्यक्ष शिक्षण के माध्यम से की जाए।

(2) सेवारत शिक्षकों के विषय ज्ञान को अद्यतन करने व संबंधित विषय में नए शोध आदि की जानकारी हेतु रिफ्रेशर कोर्सों को अधिक व्यापक बनाया जाए। इनमें शिक्षकों की सहभागिता को अनिवार्य कर दिया जाए।

(3) शिक्षकों का मूल्यांकन प्रतिवर्ष छात्रों द्वारा किया जाए। प्रमोशन के समय अन्य बातों के साथ ही इस मूल्यांकन को भी एक मानक माना जाए। हालांकि, शिक्षकों द्वारा इसका कड़ा विरोध किया जाएगा।

❑ **क्रेडिट और सेमिस्टर सिस्टम :** यह आवश्यक है कि भारत में शिक्षा के हर स्तर के पुनर्गठन के लिए 'क्रेडिट एंड सेमिस्टर सिस्टम' (सी एस एस) लागू किया जाए ताकि विद्यार्थी अपना मनपसंद पाठ्यक्रम चुन सकें। मनपसंद पाठ्यक्रम के चुनाव द्वारा छात्र कई वैकल्पिक विषयों का ज्ञान प्राप्त कर अपने व्यक्तित्व का विकास कर सकेंगे।

सी एस एस के माध्यम से कालेज के निर्धारित पाठ्यक्रम की सूची के अंतर्गत आने वाले विषयों में से छात्र अपनी पसंद के विषय चुन सकेंगे। उदाहरणार्थ भौतिक विज्ञान में स्नातक डिग्री लेने वाला छात्र आज कला, मानविकी, सामाजिक विज्ञान एवं प्राकृतिक विज्ञान आदि विषयों से पूर्णतः अनभिज्ञ रहता है। हमारी शिक्षा पद्धति में आज सबसे बड़ा दोष यह है कि छात्रों का देश अथवा संसार की सामाजिक-आर्थिक वास्तविकताओं से कोई नाता नहीं है। उनकी दुनिया पुस्तकों और परीक्षाओं तक ही सिमट कर रह गई है। सी एस एस पद्धति द्वारा शिक्षा को अधिक रुचिकर एवं सार्थक बनाया जा सकेगा। इससे विद्यार्थियों में विषय को समझने के बजाय रटकर याद करने की प्रवृत्ति भी घटेगी।

❑ **शिक्षक-छात्र के बीच रचनात्मक संवाद :** नई शिक्षा पद्धति का आधारभूत सिद्धांत यह है कि इसमें शिक्षा को "वर्तमान और भविष्य में बेजोड़ निवेश माना जाता है।" किंतु इस सिद्धांत पर विचार करते समय प्रचलित गुरु-शिष्य संबंधसूत्रता की न तो अनदेखी की जा सकती है और न ही उसका महत्व कम करके आंका जा सकता है। यह संबंध हमेशा शांत और व्यवहार्य नहीं होता। छात्र हमेशा ज्ञान प्राप्त करने वाले और शिक्षक हमेशा ज्ञान-दाता नहीं होते। इसमें कुछ चिंताजनक अंतराल पाए जाते हैं। नई शिक्षा नीति के अनुसार शिक्षा की भूमिका संस्कृति संक्रमण को दूर करने में होती है, "........ शिक्षा उन संवेदनाओं और अवधारणाओं को परिष्कृत बनाती है जो राष्ट्रीय शक्ति, वैज्ञानिक मानसिकता एवं मस्तिष्क और आत्मा की मुक्तता में योगदान करती है और अंततः हमारे संविधान में वर्णित समाजवाद और लोकतंत्र के लक्ष्यों को हासिल करने में सहायता करती है।" क्या वर्तमान उच्च शिक्षा पद्धति संक्रमण दूर करने के इस कार्य को पूरा करती है? इस प्रश्न की गहराई से जांच की जानी चाहिए।

पाठ्यक्रम हमेशा अद्यतन नहीं होता। इसमें शिक्षा के क्षेत्र की ताज़ा गतिविधियों को शामिल नहीं किया जाता। कक्षा में पढ़ाई गई सामग्री ज्ञान प्राप्ति की एक मात्र या प्रमुख पद्धति होती है। यहां तक कि कक्षा में शिक्षण भी प्रेरक नहीं होता। इसकी शुरुआत और अंत एकालाप में होता है। शिक्षक और छात्रों के बीच संवाद या विचार-विमर्श न के बराबर हो पाता है।

निःसंदेह सेमिनार, कार्यशालाएं, ट्यूटोरियल्स, फील्ड वर्क, आदि नई पद्धतियां शुरू की गई हैं। किंतु, इन्हें यांत्रिक रूप में स्वीकार किया जाता है और शिक्षकों तथा छात्रों की ओर से पर्याप्त प्रेरणा व रुचि इनके प्रति नहीं दिखाई जाती। अतः इन कार्यों में हमें छात्रों की गतिशील और रचनात्मक भागीदारी देखने को नहीं मिलती। छात्रों और

अध्यापकों दोनों में ही समय गुज़ारने का रवैया देखने को मिलता है। यह स्वस्थ प्रवृत्ति नहीं है। इससे भी उच्च शिक्षा का लक्ष्य पूरा नहीं होता। अतः छात्र और शिक्षक के बीच रचनात्मक संवाद बनाने की तीव्र आवश्यकता है।

❑ **'तनाव' दूर हो :** हाल में ही यह देखा गया है कि छात्रों और उच्च शिक्षा संस्थानों के प्रबंधकों या आयोजकों के बीच तथा शिक्षकों और कालेजों तथा विश्वविद्यालय प्रबंध समिति के बीच तनाव बना रहता है। ऐसा तनाव क्यों व्याप्त रहता है? यह प्रश्न सामाजिक-आर्थिक मूल्यों और हितों के व्यापक संदर्भ में विचारणीय है। इनका संबंध सत्ता, अधिकार और शिक्षक समुदाय सहित समाज के विभिन्न वर्गों के बीच प्रधानता के प्रश्न के साथ है। प्रो. इकबाल नारायण (1971) ने अपनी पुस्तक 'पेजेज़ फ्रॉम द वाइस चांसलर्स डायरी' में विश्वविद्यालय मामलों के इस दुर्दांत पक्ष की ओर हमारा ध्यान अकर्षित किया है। यह ऐसा दस्तावेज़ है, जिसमें युक्ति संगत ढंग से स्पष्ट तौर पर चीज़ों को रखा गया है। उक्त तनाव के निराकरण में यह दस्तावेज़ हमारी सहायता कर सकता है।

❑ **छात्र/शिक्षक की अक्षमताएं दूर की जाएं :** कुछ अपवादों को छोड़कर उच्च शिक्षा के लिए आने वाले छात्र शैक्षिक मांगों (अकेडमिक डिमांड्स) को पूरा करने में पूरी तरह तैयार नहीं होते, उनमें प्रश्न करने की प्राथमिक क्षमता या विश्वास की कमी होती है। उनमें पढ़ने और लिखने की आदत की भी कमी होती है। वे पूरी तरह पाठ्यपुस्तकों और गाइड पुस्तिकाओं पर निर्भर होते हैं, और उनके द्वारा अन्य स्रोतों का उपयोग करने का कोई प्रयास नहीं किया जाता। अतः उनका दृष्टिकोण संकीर्ण रहता है, वे मिथ्या ज्ञान की सीमाओं में आबद्ध रहते हैं और निराशाजनक ढंग से ज्ञान के तथाकथित उद्योग पर निर्भर करते हैं जो उन्हें अभिभूत और अधीनस्थ बनाए रहता है।

शिक्षक सामान्यतः इन अक्षमताओं पर ध्यान नहीं देते और न ही वे इस चिंताजनक वातावरण को अपनी व्यावसायिक क्षमता के समक्ष चुनौती मानते हैं। वे इन अक्षमताओं को अपनी उस भूमिका के प्रति लज्जाजनक भी नहीं मानते, जिसमें उन्हें छात्रों के व्यक्तित्व तथा चरित्र-निर्माता की नैतिक ज़िम्मेदारी निभानी होती है। बल्कि वे इन अक्षमताओं के प्रति समर्पण कर बैठते हैं। अब अक्सर यह कहा जाता है कि शिक्षकों की अध्यापन क्षमता के मानदंड कम होते जा रहे हैं। वे दिन-प्रतिदिन छात्रों के साथ 'समायोजन' करने का प्रयास करते जा रहे हैं और इस प्रक्रिया में ज्ञान तथा विद्वत्ता के प्रति चिंता के अवसर गंवाते रहते हैं। अनुकूलन और समायोजन की यह संस्कृति आगे चलकर एक प्रचलित विचार या प्रमुख लोकाचार बन जाती है। जो शिक्षक इस लीक से हटने का प्रयास करता है और जो रचनाशीलता के मानदंड बनाए रखने के लिए संघर्ष करता है, उसे नीचा समझा जाता है या वह सामान्यतः उन शिक्षकों द्वारा अलग-थलग कर दिया जाता है, जो इस समायोजन संस्कृति की मुख्यधारा का निर्माण करते हैं। परिणामस्वरूप, परिश्रमी अध्यापक जो अल्पसंख्यक होते हैं, किनारा करने के लिए मजबूर हो जाते हैं। न तो प्रबंध समिति और न ही साथी शिक्षक

उनकी बात सुनने के इच्छुक होते हैं। इस अस्वास्थ्यकर पद्धति को संगठित प्रयासों से बदला जाना चाहिए।

❑ **अन्य सुझाव :** नियमित सत्र, अकादमिक कलैंडर, परीक्षा की पवित्रता, आर्थिक निर्भरता, शिक्षा को सामाजिक समस्याओं से जोड़ना, शिक्षक को जवाबदेह बनाना, कालेज प्रशासन की प्रत्येक स्तर पर जवाबदेही निर्धारित करना, राजनीतिक हस्तक्षेप को रोकना जैसे कदम भी उच्च शिक्षा में त्वरित गुणात्मक सुधार के लिए ज़रूरी हैं।

उच्च शिक्षा व्यापक सामाजिक-आर्थिक और राजनीतिक नेटवर्क की उपज है। उच्च शिक्षा को प्रभावित करने वाली विभिन्न नकारात्मक प्रवृत्तियों की जड़ें, व्यापक सामाजिक-आर्थिक परिस्थितियों में होती हैं। इन विसंगतियों की ओर व्यापक सामाजिक तथा राजनैतिक आंदोलन ही ध्यान आकृष्ट कर सकते हैं और वे ही उनमें सुधार ला सकते हैं। उच्च शिक्षा के क्षेत्र में संख्यात्मक वृद्धि तो अवश्य हुई है बल्कि कहा जाए कि अतिशय हुई है परंतु यह वृद्धि न केवल अपर्याप्त है अपितु प्रत्यक्षतः हानिकारक भी है। ऐसी शिक्षा के स्थान पर राष्ट्रीय प्राथमिकताओं, राष्ट्रीय परिवेश एवं अंतरराष्ट्रीय दृष्टिकोण से सार्थक शिक्षा का विकास करना होगा। ❑

प्रकाशन प्रभाग में अध्यक्ष, राष्ट्रीय शैक्षिक अनुसंधान और प्रशिक्षण परिषद्, श्री अरविंद मार्ग, नई दिल्ली-110016 द्वारा प्रकाशित तथा सुविधा कंप्यूटर्स, 86 ए, अधचिनि, श्री अरविंद मार्ग, नई दिल्ली 110 017 द्वारा लेज़र टाइपसैट होकर ताज प्रिंटर्स, मोती नगर, नई दिल्ली में मुद्रित।

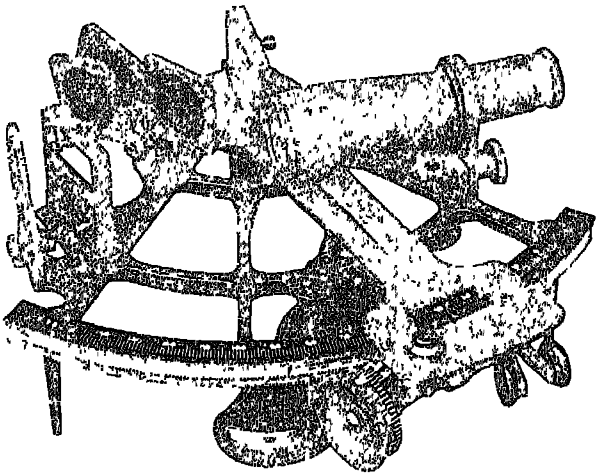


FIG 12 A standard type of sextant (Courtesy, Leupold & Stevens Instruments, Portland, Ore)

ORGANIZATION OF PARTY. One sextantman (two if two sextants are available), soundingman, recorder, boatman, assistant. The size of the party may be less than the five indicated above if necessity demands

Procedure

1 Examine shore-line map of lake, or the lake itself if preferred; select carefully a series of natural objects, or erect artificial signals along or near the shore line the exact location of each of which can be accurately indicated on the shore-line map These objects are to serve as *signal stations.* Each signal station must be distinctive and positively identifiable from sounding boat, they must be far enough apart so that no angle between any two of them is very small, but on the other hand they must not be more than about 120° apart, and must be so distributed about the lake margin that from all lake-surface areas at least *three adjacent signal* stations are clearly visible For suggestions concerning artificial signals, see pp 45–46

2 Organize the boat party and review with the whole party all the procedures to be followed in the field Supply oarsman, engineman, or helmsman with a small sketch map showing courses to be followed by the boat to cover the lake area adequately—courses to be steered blindly or with guidance of shore objects

3 Sounding operations may now begin Sounding boat chooses position No. 1 and comes to halt, soundingman makes sounding with line and lead, or with sounding pole if in shallow water, and announces sounding

to recorder, recorder makes record and repeats entry aloud. Soundingman reads line or pole second time and repeats announcement or announces correction if error was made. While sounding is being made, sextantman chooses a group of 3 easily visible shore signals (for example, 8, 9, and 10, if numbered signals are used), and with index arm of instrument set at zero, or at correction position, directs sight tube on shore signal (No 8), then moves index arm until adjacent shore signal (No 9) seen in lower part of horizon glass coincides with first signal seen through upper part of horizon glass. Index arm is then clamped and the vernier read, the angle between the two signals is read aloud to recorder who enters reading on record form and repeats the entry aloud Sextantman

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FORM 4

FIELD RECORDS

Location of Sounding Positions by Sextant

Lake

Date

Wind

Sky

Sextant No.

Sextantman

Recorder

Boatman

Soundingman

Kinds of Signals Used

Sounding Apparatus

Corrections
Sextant Index Error
Sounding Line Errors

Position No	*1st Angle*		*2nd Angle*		*3rd Angle*		*Sounding (m)*	*Remarks*
	Signals Used	*Angle*	*Signals Used*	*Angle*	*Signals Used*	*Angle*		

reads vernier a second time and repeats announcement or announces correction if error has occurred. Then sextantman resets sextant at zero point, or at correction point, and directs sight tube at middle signal of selected trio (No 9), moves index arm until third (No 10) signal coincides with first signal (No 9) Index arm is clamped and the angle between the second and third signals is read and recorded as described above The two angles so determined locate the sounding position

4. Sounding boat proceeds to another position and the operation described in paragraph 3 is repeated with the exception that sextantman may choose same shore signals as before if satisfactory for his purposes, or he may choose another trio. Trios of shore signals are chosen in such combinations and in such positions as best facilitate the location of sounding positions.

5. There are some advantages in distributing sounding positions along ranges, although this procedure is sometimes ignored

General Considerations

a. Sextant should be checked frequently for index error.

b. When shore signals or objects are definite and readily identifiable by the unaided eye, a sextant without telescopic equipment is no disadvantage, in fact under some circumstances there may be an advantage

c. When used on small boats, the sextant should be equipped with a strap or cord by means of which it can be attached to the observer as a safety measure

d. Considerable practice is necessary in order to become expert in the use of a sextant Inexperienced persons should have drill, preferably under direction, before undertaking to locate sounding positions in the field.

e. If soundings are made from a boat in continuous forward motion, two sextants and two sextantmen are needed, one measuring one angle and the other the second angle simultaneously The soundingman must be experienced in line casting, if sounding is done by hand, in order that the sounding value may be secured when the line is vertical. If the sounding is done by means of a sounding machine, the angle of inclination of the line must be measured and the proper correction made.

f In measurement of horizontal angles with the sextant, it is important that the distances between sextant and shore signals be considerable. The constuuction of the instrument is such that when close-up signals are used errors are introduced.

g Ordinarily, in the measurement of angles between two objects on shore, the sight tube should be directed at the fainter one if there is any appreciable difference. Since the index mirror is to the right of the sight

tube it will be necessary to hold the sextant upside down if the fainter object is on the right However, the operator will be able to judge whether sighting on the fainter object is necessary

h. If difficulty is experienced in picking up certain signals with the sextant, the work will be facilitated if the sextant can be set at roughly the angle to be measured This approximate setting of the instrument may be accomplished as follows Hold the hand at full arm's length in front of the eyes and spread the thumb and fingers to their widest position; then determine the angle subtended between the ends of the thumb and the little finger. With this rough value determined it is possible, with the hand in this position, to step off an approximate angle between two objects on shore

i. Whenever there is more than one choice of signals in determining any position on the water, those which yield the strongest position—that position easiest to observe and plot with certainty—should be selected. Strong positions occur (1) When sounding boat is within the triangle formed by the three shore signals. (2) When the three signals are nearly in line, or the middle signal is nearer the sounding boat than the others, and all angles have a magnitude of 30° or more. (3) When two signals, remote from each other, are in range and the angle between the second and third signal is not less than 30°. Under these circumstances the boat position is determinable from the one angle (between middle signal and the one not in line) but it may be desirable to measure an angle between the signal not in range and a fourth one just for a check.

j. Further guidance in the choice of shore stations may be secured from the following directions (1) Avoid small angles as a general procedure. (2) Avoid the use of fixed shore objects as signals if they have considerable difference in elevation and one of the pair is near the observer (3) Avoid the use of signals when the distance between two of them is small compared with the distance from the observer. (4) Avoid using signals which are very close at hand, instead, choose signals on opposite side of lake or on some other remote situation, provided the distance is not so great as to detract from the accuracy of the work (5) Avoid the selection of any three shore signals whose positions happen to fall on the circumference of the same circle drawn through them. If such a selection must be used then it is imperative that the sounding boat positions be kept remote from the periphery of such a circle since such positions are not determinable. Only by the use of a third angle can such a position be located

k Shore objects or signals which are to serve as fixed positions for sextant sounding work must be in visible positions; must be individually and certainly identifiable from the sounding boat; must be situated in carefully chosen and strategic places, and must be *accurately located* on

the shore-line map. If natural physiographic features on shore or artificial permanent constructions on shore meet the requirements just mentioned they may be used However, occasions are likely to be rare when such objects are sufficiently distinctive and adequately distributed. Consequently, specially made signals must be provided. Satisfactory and relatively simple signals may be made in the following ways (1) Boards, at least 8 in wide and 4 ft long, nailed together in the form of a cross, painted white, and fastened substantially to the top of an 8- or 10-ft. post. Such crosses may be spiked to trunks of trees along shore if such mounting does not interfere with their visibility. Combinations of white and red painting of such crosses will facilitate individual identification if such aid is needed. (2) Narrow boards or barrel staves may be arranged in the form of Roman numerals and nailed across the top of a tall pole, thus indicating the identity of the signal Visibility is improved if these boards or staves are painted white. (3) Two boards, 3 in wide and 2 ft long, may be nailed crosswise to a pole or tall post, one at the top and the other at a distance below it about equal to its length, forming two horizontal arms. Sheets of cloth—red, white, or both—are stretched across the space between the arms and tacked firmly to them (4) If one or more signals must be set in shallow water, a satisfactory construction is made as follows three pieces of iron pipe, each about 12 ft. long and of suitable diameter, are securely tied together at one end, the untied ends are spread well apart in the form of a tripod and sunk firmly into the bottom materials, flags of white, red, or both white and red cloth, about 1 5 ft square, nailed to staffs the lower ends of which will just fit snugly inside the pipes, are installed at the top of this tripod Sometimes an addition to this type of signal consists of two strips of cloth wrapped around the tripod about midway between the water surface and the top.

l On occasion it may be desirable, or even necessary when other well-located shore objects or signals are lacking, to measure an angle on a well-defined tangent to the end of a peninsula, the end of an island, or some other permanent physiographic feature Such procedure may give acceptable results if carefully done and if the features used are not too remote from the sounding boat

m If signals are to have any permanence, as might be desirable in many instances, the following suggestions should be considered (1) Construct principal parts of substantial and weather-resistant materials, (2) install shore signals above high-water and ice-action line, (3) set posts deep into the ground, and (4) paint both wood and metal parts

n. Artificial shore signals should be located where good judgment indicates. Avoid using a larger number of such signals than is strictly necessary. The exact position of each should be marked by an iron stake, two feet long, driven completely into the ground and its position refer-

enced in relation to adjacent permanent objects. Such procedure will make it possible to restore the signal if it is destroyed

o Artificial shore signals may, if desirable, be located at some distance landward from the shore line provided they meet all other qualifications of good signals

p At least some of the artificial shore signals should, if possible, be located at traverse stations or at local triangulation stations used in mapping the shore line. Such stations presumably are accurately located on the map and will facilitate the location of other signals.

Plotting of Field Data

1. This method presupposes the availability of a shore-line map of the water sounded Such a shore-line map must be of such a scale that soundings can be located on it with reasonable ease, accuracy, and without crowding. Very small maps are not usable If necessary, enlarge the shore-line map by any one of the approved methods (p. 77). Shore-line maps which are just included within a 36 × 36-in sheet will usually be adequate for most inland lakes.

2. On the shore-line map locate with all accuracy possible the positions of the natural objects or the artificial shore signals used in the field work. If the original stations used in the shore-line survey have been retained on the map and if some of such stations have been used for signal positions for the sounding work, the plotting will be greatly facilitated as will also the location of the positions of other signals used. Unfortunately, such original survey stations are too often omitted from finished hydrographic maps. If the shore-line map has been made under the same authorship as that of the sounding work, shore-line signal positions will be properly located and available, but if a shore-line map of another authorship is employed, the shore signals must be located by whatever means best suits the circumstances. Then recourse must be had to objects definitely located and identified on the shore-line map, such as adjacent road intersections, large permanent buildings, lighthouses, large permanent piers, causeways, mouths of inflowing streams, beginnings of outlets, old sawmill sites; angular peninsulas, and other usable features.

3 Sounding positions which have already been located in the field by the three-point method can be plotted on the map most conveniently and rapidly by the use of a three-arm protractor. The high-class, metal three-arm protractors are superior instruments but because of cost may not be available Somewhat less expensive celluloid three-arm protractors may be secured. If no three-arm protractor is available, a usable substitute may be provided as follows For each sounding record, draw three lines on a piece of tracing paper or other translucent material so that the two measured angles are included between the lines Shift the pattern of lines so prepared

over the shore-line map in the general vicinity of the shore signal positions used for that particular record until the three lines pass exactly through the three points; in this position, the point of union of the three lines (the apex) represents the position of the sounding position and may be pricked through into the underlying map with a needle. Three-arm protractors are used in a similar fashion, the sounding position being determined when the proper edges of the accurately set protractor arms cut through the middle of the three points. The plotting of positions is likely to be facilitated if some uniform method of placing the protractor or the three-line pattern on the map is followed, such as that of placing the middle arm or middle line on the middle shore position with the other arms or lines about equidistant from the corresponding shore positions and then pushing the center of the instrument or pattern toward the shore signal positions, shrinking the distances about equally on the two sides until the proper edges of the protractor or the lines of the pencil pattern exactly bisect the station points.

4. When a sounding position is located on the map, the sounding value should be entered on the map as described on p. 68. These procedures are repeated in like fashion until all soundings are recorded.

OTHER METHODS

Counting Oar Strokes. If instruments are lacking, or if the usually expected accuracy is not required, ranges may be established somewhat as illustrated in Fig. 9 and soundings may be made along such ranges by using a selected number of oar strokes to determine distance between soundings. If the average distance covered by one oar stroke by oarsman is determined, and the positions, directions, and lengths of ranges are known, it is possible to chart soundings made in this way. Obviously, such a method can give only gross results. Calm water conditions are a necessity.

Plot field data by laying off selected ranges on shore-line map, scale distances along each range line and locate soundings as determined by field data. Conclude map in the usual way.

Location by Time Intervals. Under conditions somewhat similar to those mentioned in the section above, distances between soundings may be determined by the time interval involved. Ranges are laid out and the boat follows them in a definite order. If the approximate speed of the boat is known, the distance between soundings taken at stated intervals can be determined roughly. The limitations of this method are obvious. Plot data on map as described above and finish with data listed on pp. 68–69.

Improvised Instruments

In the absence of standard surveying instruments, satisfactory mapping can sometimes be done with improvised equipment if proper care is

used, if the principles of the methods are understood, and if only small areas and distances are involved. The limitations of such home-made apparatus must be thoroughly understood and not exceeded. The following suggestions will indicate something as to the possibilities in this direction

PLANE TABLE By means of sturdy attachments, mount an ordinary drawing board, about 20 × 20 in in dimensions, on a heavy tripod of convenient height and provide means of rotating and immobilizing the board Select a good grade, flat, wooden ruler, 12–14 in. in length, graduated accurately to 1/16 in or finer on one edge and in centimeters and millimeters on the other edge, near each end of the ruler in mid-line position drive a small brad in a vertical position, leaving about ½ inch of each brad projecting above surface of the ruler A ruler, so modified, constitutes a rough alidade, the brads serving as sights Add to this equipment a small pocket compass, range rods, tapes or graduated ropes, and chain pins, all of which can be improvised if necessary, and a workable plane-table outfit is provided Very accurate maps of small areas may be made with such rough equipment In such an outfit all distances must be measured by taping.

INSTRUMENT FOR MEASURING ANGLES Mount, by sturdy attachment, a small drawing board about 16 × 16 in in size on a heavy tripod. Attach firmly to the upper surface of this board a full-circle, 12-in diameter, protractor, graduated to ¼ degree and with the whole degrees numbered by two sets of figures which increase from 0 to 360 in opposite directions Prepare a slender wooden or brass pointer, slightly longer than the diameter of the protractor; attach to each end of the pointer, on mid-line, a slender pin to serve as a sight Near one end of the pointer cut a slender, oval window about 1 in long and seal a very fine wire or thread lengthwise on the top surface of the window to coincide exactly with the midline connecting the two sights, install a vertical axis or pivot in the middle of the pointer and set firmly at center of the protractor Construct the pivot so that the pointer can be rotated, not loosely, over the protractor in very close proximity to but not in actual contact with it In this position the pointer window should extend across the graduated scale on the protractor in all positions and the hair or thread across the window serves as a means of reading the angles This window must be wide enough to enable the observer to read the graduated scale accurately

Such a rough instrument may, on occasion, be used as a substitute for a transit and with proper care and understanding good results may be obtained in simple mapping of small areas

AERIAL PHOTOGRAPHIC MAPPING

Rarely if ever is it possible for the limnologist to make aerial photographic maps He must depend upon those prepared by certain branches of the government or perhaps by commercial companies which specialize

in that kind of work In certain parts of the United States, large areas have already been mapped from the air and excellent maps may be secured from the various sources, although cost is still a consideration Since such maps are not usually made specifically to serve the needs of the limnologist, careful selection is necessary When made on a scale large enough to be serviceable, or when enlarged to usable size from the originals, these maps may yield valuable information otherwise difficult to get They serve as excellent checks on ground surveys, particularly in such features as form of shore line, fixed points on shore, and position and extent of shallowly submerged shoals Because of their nature, the accurate interpretation of aerial photographic maps requires experience on the part of the observer, hence conclusions of a beginner should be carefully checked by someone familiar with the problems of air-map reading It must be understood that, for limnological purposes, no aerial photographic map is a substitute for a standard hydrographic map since it does not supply information on many salient features such as detailed soundings, form of basin, and character of bottom

Additions to Lake Surveys

Limnological needs in lake surveys often require information in addition to that supplied by the conventional hydrographic map Bottom materials and deposits in the various areas, character of the banks, degree of shading of banks, aquatic vegetation in the various areas, and special features of inflowing water, flood levels, artificial features, and any other significant characters require field study for their incorporation on the maps. (See pp 71–75 for suggested symbols, descriptive designations and other characters useful in such mapping.) Information basic to the charting of these features should, if possible, be secured immediately after the shore line and basin have been surveyed, while all stakes and other established points are still in position Surveys of the various bottom areas, vegetation areas, and similar features may be made by modifications of methods already described. Transects, spread in significant patterns and definitely located with respect to fixed points on shore, constitute one of the best methods Stations along transects or scattered on the open water may be located by any of the methods described for location of sounding positions.

For Selected References, see p 59

STREAM SURVEYS

Streams, like lakes, may be mapped by various methods Those described here are useful for streams of smaller size (creeks and brooks) Larger units of the running water series (rivers) may be mapped by the proper adaptation of certain methods described in this chapter and in the preceding ones.

Deflection-angle Traverse

In a deflection-angle traverse the direction of each successive axis line is established by measuring the angle that the last line makes with the forward prolongation of the preceding one The same result is obtained if, instead of a deflection angle, the angles which are formed by the two lines of a course without prolongation are used, but deflection angles are mostly smaller in magnitude, easier to plot, and on certain kinds of instruments are easier to read

Suitability This method, as outlined here, is especially suitable for mapping small streams whose widths and depths are such that the traverse can be made in the channel, or for streams whose shore conditions are such that, if the traverse cannot be in the channel, it can be run on either bank or along either water edge

Equipment Transit; stadia rod, range rod, ax, wooden stakes; chain pins on carrying ring, with colored cloth tied in upper ends, crayon for marking stakes; 100-ft steel tape, or 100-ft graduated rope, sounding pole, megaphone; forms for records

corrections and adjustments Examine transit, stadia rod, and tape or rope for accuracy and good condition

Organization of Party Transitman, stadia-rodman, range-rodman, two tapemen, assistant.

PROCEDURE

1 Make preliminary examination of stream or portion of stream to be surveyed in order to anticipate any special problems peculiar to the task. It is necessary to determine in advance whether it is practicable to run the traverse in the stream bed, whether it must be run on the bank, or whether a combination of channel and bank course must be used The following description will assume a traverse run in the channel.

2. Select initial transit station (Fig. 13, *A*), drive iron stake at this

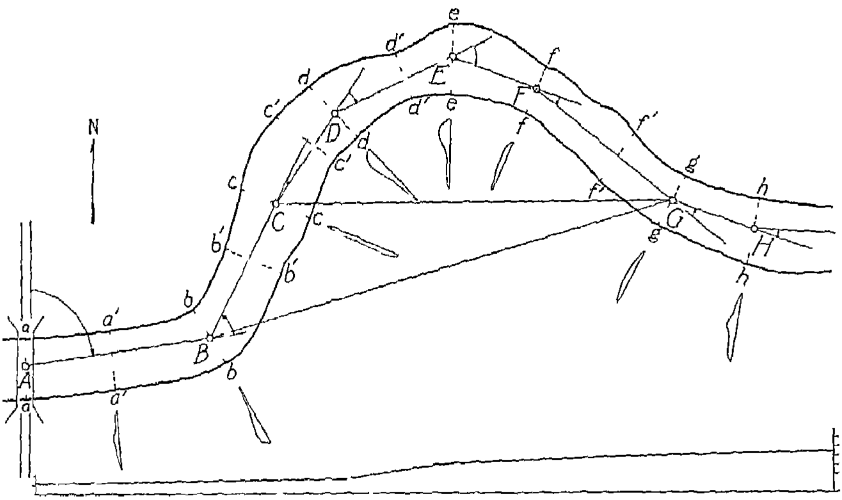


FIG 13 Diagram illustrating deflection-angle traverse of a portion of small stream Traverse is run in stream channel Curved arrows represent deflection angles. (*A–H*) Transit stations (*aa–bb*) Positions of measurements of channel widths at transit stations (*a'a'–f'f'*) Positions, intermediate between transit stations, at which measurements of channel widths were taken (*CG*, *BG*) Checks on position of transit station *G*. Survey is represented as beginning at bridge where road crosses stream

Diagrams opposite *a'*, *b*, *c*, *d*, *e*, *f*, *g*, and *h* represent transverse *depth profiles* of channel at those positions. In these profiles, scale for width is same as that of map of stream; but scale for depth has been exaggerated by multiplying all depth data by some stated value, a procedure made necessary by very shallow depths of water Different scales may be necessary in profile mapping, depending upon conditions of stream involved. However, scales of profiles must always be definitely stated in detail

Profile at bottom of figure represents fall in level of stream made according to some convenient scale Value of such scale must always be clearly stated

point and reference it to adjacent, permanent objects. It may be convenient to begin survey at road intersections, bridges, or other easily identifiable positions.

3. Set up transit on initial station *A*; choose next station in direction in which survey is to proceed and as far in advance as contour of stream will permit line of sight to remain well within borders of channel (unless distance is unusually long, then intermediate stations must be established). Mark and drive stake *B*, direct transit on signal at *B* and carefully take magnetic bearing, also, if starting at intersection of some already established survey line or road, determine angle which line *AB* makes with such line or road.

4. Erect stadia rod on *B* and determine distance *AB*

5. At *A* and at significant intervals *a'a'* between *A* and *B* make transverse measurements of stream, water edge to water edge, or bank to bank, or both as desired. Make such measurements so that distances, right and left, from line of sight *AB* to each channel margin are recorded, also determine distance of each transverse measurement from *A* Drive stakes at all such positions and mark on each with crayon its identification symbol or number.

6. At all positions of transverse measurements, make water-depth measurements as follows in middle of stream and at least at mid-distance between middle and each bank (three measurements) Distances of depth measurements from each other and from line of sight *AB* must be known and recorded Use more than three depth measurements in very wide streams.

7 Transfer transit to *B*; direct telescope on range rod set on *A* and set transit scale at zero, either reverse telescope on its horizontal axis ("plunge telescope") or reverse telescope on its vertical axis ("reverse in azimuth") exactly 180° thus prolonging line *AB* Select position next in advance *C*, mark and drive stake, label and erect signal, direct telescope on *C* and determine angle of line *BC* with prolongation of *AB* (deflection angle) Record deflection angle as *Right* or *Left* depending upon how the new line of sight relates itself to the prolongation of the previous one, erect stadia rod on *C* and determine distance *BC*

8. Make transverse-channel and water-depth measurements at *B* and between *B* and *C* as described in paragraphs 5 and 6 and keep all necessary records

9 Proceed with survey, successively establishing positions *D–H* and determining all distances, deflection angles, transverse measurements, and depth measurements as already described. Record magnetic bearings of some or all lines of sight for checks

10 In surveying tortuous streams in open, unwooded areas, check sections of traverse by setting up triangles from place to place, as for example in Fig 13 establish *G* at beginning of survey of that section of stream and mark with signal Determine angle *GBC* when transit is at *B*, angle *BCG* when transit is at *C*; with these angles and the length of line *BC* known the position of *G* can be computed or plotted Or, if distances and visibility will permit, defer check until *G* is reached in traverse, determine distances *GB* and *GC* by tape or stadia rod, then lengths of all sides are known, also one angle, and the position of *G* can be determined by plotting or computation

11 For additions to the survey, especially for biological purposes, see pp 71–75

General Considerations

a When the traverse must be run on the bank, or at the water's edge, most of the necessary modifications of the method as described above are obvious and need not be enumerated here. A bank traverse often requires considerable clearing of vegetation from lines of sight.

b. If necessary or desirable, a combination of channel and bank traverse can be employed by merely transferring with known angles and distances, the general course of the traverse from channel to bank or from bank to channel

c If a stadia rod is not a part of the equipment, all distances can be measured by means of steel tapes, chains, or graduated ropes.

FORM 5

FIELD RECORDS

Deflection-angle Traverse

Stream	Transitman
Section Surveyed	Recorder
Date	Rodmen
Transit No.	Tapemen
Tape No.	

Station	*Deflection Angle*	*Distance*	*Bearing*		*Remarks*
			Magnetic	*True*	

d. The number of transverse-channel and water-depth measurements must depend upon the variation in the physical features of the stream and upon the precision desired in the survey For ordinary purposes and in sections of the stream where the channel is quite uniform, the number of transverse measurements can be reduced to a minimum

e. In a channel traverse, great care must be used in setting up the transit to insure against changes in position due to water flow, walking about the tripod, and other causes. Soft bottoms are particularly troublesome In case of doubt revert to backsight and reread the angles.

f. It is possible, and sometimes desirable, to combine with the survey the determination of stream channel elevation so that a level profile can be constructed However, this should not be attempted unless the transitman or leader of the party is familiar with the principles and practices of measuring levels

g A traverse similar to the kind described in this section can be made, with less precision, by using a surveyor's field compass instead of a transit In such procedure, angles must be read in the compass box and depend upon magnetic bearings, also all distances must be measured by lines or tapes.

PLOTTING OF FIELD DATA

1 Determine scale suitable for size of map desired

2. Locate initial station (Fig. 13, *A*) of transit so that map will occupy paper in desirable position, make pencil dot, surround dot with small penciled circle, and label it *A*.

3 Establish north-south line through *A*

4. Draw transverse line *aa* through *A* and scale channel width at that level, mark positions

5. With protractor centered at *A*, draw line *AB* according to magnetic bearing recorded in field data, check with any angular measurements provided in field notes.

6. Scale distance *AB* and locate *B* with pencil dot surrounded by small penciled circle.

7. Scale distance *A* to intersection of *a'a'*; draw transverse line representing *a'a'* at right angle to line *AB*, scale distance *a'a'* and mark positions *a'* and *a'*. Proceed similarly with other transverse measurements of channel between *A* and *B* if more than one was made in field.

8 Transfer protractor to *B*, protract deflection angle from a prolongation of *AB* and draw line *BC*; scale distance *BC* and locate *C* by pencil dot surrounded by small penciled circle.

9. Bisect angle *ABC* and draw transverse line *bb*; scale distance *bb* and locate *b* and *b* as determined by field data. Mark positions *b* and *b*.

10. Scale distance *B* to intersection of *b'b'*; at right angle to *BC* draw

line $b'b'$ and scale distance $b'b'$ as determined by field data, mark positions b' and b' Proceed similarly with other transverse measurements of channel between B and A if others were made

11 Connect with firm pencil line positions a, a', b, b' and any intermediate ones to outline one bank of channel and similarly connect positions a, a', b, b' and any intermediate ones on other side to form other bank of channel

12 Proceed in similar way with other lines and deflection angles until map is completed Apply all check information taken in field operations to test accuracy of map

13. On one side of map of channel when completed draw cross-section depth profiles, using same horizontal scale as employed in mapping channel (or if desirable use an enlarged scale), at each position representing levels at which depth measurements were made (Fig. 13). In very shallow streams, a much larger *depth scale* will be required to make profiles show sufficient depth to be useful Be sure that the various scales employed are indicated on the map.

14 When channel map and profiles are completed, remove all construction lines, and add usual map information as specified on pp 68–69

15. If channel-water levels have been measured in connection with field work, then construct at the bottom of the map an elevation profile, using some convenient height scale, which will show channel slope.

16 If desired, add to the map such words, symbols, and abbreviations as will indicate the character and distribution of the various stream characters which have limnological significance, as for example, bottom materials, character of banks and aquatic vegetation (pp. 71–75) To avoid congestion of the map it may be necessary to make more than one copy in order to represent properly all such features Colored shading may be used effectively to incorporate areas of different kinds of bottom materials and similar data For specific indication or naming of details, whole words may be written on the map at appropriate places, in other instances, properly chosen symbols or abbreviations (pp 69–75) may be preferable

Plane-table Traverse

In stream mapping the plane table if available can often be used to considerable advantage, particularly if a telescopic alidade with stadia cross wires is employed. This method has the well-known virtue of constructing the map on the plane-table board as the survey progresses thus making possible the retaking of readings and the adding of extra measurements when necessary. It has the disadvantage, when compared with the transit traverse method, of requiring the use of a scale small enough to bring the map within the dimensions of the plane-table board and in stream surveying this scale is often far too reduced If large-scale maps

are necessary they can be made directly by plane table only by using numerous sheets of plane-table board size, each sheet representing such section of the stream as can be included, and later assembling these sheets in proper sequence To make such assembly of sheets, care must be taken to secure in the field full information necessary to construct this assembly in correct form Some of the features of plane-table operation are described on p 17

SUITABILITY. In general, same as described for the deflection-angle traverse (p 51)

EQUIPMENT Plane table, stadia rod, range rod, 100-ft. steel tape, chain pins on carrying ring, and with pieces of colored cloth tied into upper ends, 2–3 iron stakes, wooden stakes, ax, crayon for marking stakes, several No 5 insect pins, waterproof cover for plane-table board, compass, forms for records, pencils, several sheets of good grade, heavy white paper cut to cover whole area of plane-table board.

CORRECTIONS AND ADJUSTMENTS. Examine plane table, stadia rod and steel tape for good condition

ORGANIZATION OF PARTY. Instrumentman, stadia-rodman, range-rodman, two tapemen, assistant.

PROCEDURE

1 Make preliminary examination of stream in order that survey can be properly planned Among other things, determine whether traverse can be run in the channel or whether it must be run on bank.

2. Select first instrument position (Fig 13, *A*), drive iron stake and reference it to adjacent, permanent objects If convenient and desirable, begin survey at road intersection, bridge, or some other previous survey location.

3 Set up plane table over *A*, orient board in most desirable position and lock Establish and mark north-south line on paper, establish next position *B*, drive stake, mark with sequence designation, and elevate stadia rod on it

4 Select scale to be used for mapping on plane-table board and record it on one side of paper. Estimate space and position requirements of future map on paper, choose proper position of *A* and set pin firmly at that point.

5 Set alidade with zero point against implanted pin, pivot alidade on pin and direct telescope on stadia rod at *B;* draw line along ruler edge of alidade. Read distance *AB* on stadia rod and lay off same to scale along the line just drawn, mark point and designate *B*.

6. Pivot alidade to position at right angle to line *AB*, measure distance to water's edge (or bank) on stadia rod, and draw line and scale distance Mark point on map, drive stake at shore position *a* and mark.

7. Place stadia rod at position halfway between *a* and *A* and measure

water depth at that point. (Distance and water depth can both be read on the stadia rod if water is not too deep) Record depth in field records, measure depth at *A* and record.

8 Pivot alidade 180° and measure distance to opposite edge (or bank), scale and mark, drive stake at shore position and mark Place stadia rod halfway between *A* and *a*; determine and record water depth, measure depth of water at *A* and record

9 Choose position of next transverse measurement *a'a'* and drive stake at both positions, without moving plane table, pivot alidade and sight on stadia rod at *a'*; read distance, scale, and mark on map Pivot alidade to stadia rod on other side of stream at opposite end of *a'a'*, read distance, scale, and mark. Make water-depth readings along *a'a'* at middle and halfway between middle and each water edge (or bank) with tape or graduated rope; record depths

10 Move plane table to *B*; set up carefully and rotate board until line *AB* on plane-table board coincides exactly in direction with line of sight *BA*, when alidade is rotated in working position about pin at *B*.

11 Establish next position *C* in advance and proceed with the survey as described above, including transverse-width and water-depth measurements at *bb* and *b'b'* and any others intervening between *B* and *C*. Continue thus until survey is complete.

12 In open, unwooded areas, check survey by reading backward on selected positions, as for example, in Fig. 13, with plane table at *G*, read direction and distance on stadia rod at *B*, scale distance and scaled point should fall on *B* on map.

13 Remove all construction lines, add information designated on pp. 68–69.

General Considerations

a Items *a*, *b*, *c*, *d*, and *e* on pp. 54–55 relating to deflection-angle traverse apply in general to the plane-table survey

b. A nontelescopic alidade can be used in this method, but if so, all distances must be measured with tapes or graduated lines

c If desired, complete map by inclusion of the descriptive features of the stream as mentioned and indicated on pp. 69–75

Soundings in Streams

Methods for making soundings described on pp 25–37 may be readily adapted for use on streams and need not be considered here Sounding requirements on very wide streams approximate those for lakes For narrow but deep streams, a method of making soundings along a series of parallel, transverse ranges will probably be found satisfactory and reasonably rapid Directions for the recording and mapping of sounding records as given on p 68 should be followed also in work with streams.

Aerial Photographic Maps of Streams

As in the instance of lakes, aerial photographic maps (p 48) when available and made on suitable scale, yield information of much value This is particularly true when the exact form and length of a stream, or part of a stream, is desired. Also facts concerning the drainage basin may be secured However, for the purposes of detailed stream survey or stream investigations, there is at present no satisfactory substitute for the type of ground mapping described on pp 51–58.

Additions to Stream Surveys

Certain biological needs in stream surveys require information other than stream configuration, channel widths, and channel or water depths These additions should be made if possible during the progress of the survey or immediately afterward while all of the stakes are still in position For each area definitely marked off by stations and stakes, make field records describing the features concerned Prominent among these features are the following bottom materials, character of banks, nature of flow of water, shading from bank, aquatic vegetation, character of inflowing water, high-water and flood levels; and artificial features (See pp. 69–75 for list of suggested symbols, descriptive designations, and other characters useful in mapping)

One of the best ways of making necessary field notes on the items mentioned above is the use of freehand sketches of the stream on which the various features are indicated and labeled. Such sketches may be made one section at a time and then pasted end to end at the conclusion of field work. It will usually be found convenient to use more than one such freehand sketch to avoid congestion of labels and sketched areas.

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(For Chapters 1–3)

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"Surveying Tables" 392 pp Technical Manual, War Dept, Washington, D C, 1940

Swainson, O W "Topographic Manual" 121 pp Spec Pub No 144, U S Coast and Geodetic Survey, 1928

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WATER LEVELS

Since water-surface elevations fluctuate, sometimes markedly, and since some measure of such variations is vital to an understanding of certain limnological phenomena, it is often necessary to provide means of securing dependable records of water levels and their changes

Water levels may be expressed in two ways (1) with reference to an arbitrarily selected level, or (2) in actual elevation above sea level In the first instance, total change of water level over a period of time is secured and for some purposes this information may be adequate Often, no other alternative is possible since a *bench mark*—a permanent point of known elevation—may not be available For the determination of actual elevations in terms of sea level an authoritative bench mark is required. The U S Coast and Geodetic Survey and the U S Geological Survey have established many bench marks throughout the United States, the locations of which can be secured from the offices of these bureaus These bench marks consist of circular bronze tablets, about 4 inches in diameter, cemented into rock or masonry structures or into the top of concrete posts On the bronze tablets are inscribed certain data, usually including the elevation at that point Sometimes other dependable elevation bench marks have been established by railroads, cities, or scientific organizations The extension of a level datum from a bench mark to a position on a water-level recording instrument is a task to be performed only by an experienced surveyor or by someone thoroughly familiar with the running of levels Also only instruments suitable for such work can be used If the only available bench mark is at a considerable distance and the country is rugged, it may not be feasible to attempt to extend such a level unless the project of measuring water levels is to be one of more than usual importance and duration Local bench marks, once established, should be fully protected against damage or alteration; also the level datum which they represent should be extended to other adjacent permanent objects and so marked that the elevation datum can be recovered with a minimum of effort in case it is lost

Graphic Water-level Recorders

A complete, continuous record of water-level changes may be secured by the use of a graphic water-level recorder of which there are many models on the market These instruments are expensive and require, for

their best operation, an elaborate installation, but when used properly they have many points of superiority. The essential features of such an instrument are as follows a float which rides on the surface of the water, a cylinder revolved at some uniform speed by clockwork mechanism, a recording pencil or pen so adjusted that it traces the rise and fall of the float, and paper charts of suitable pattern attached to the revolving drum on which the recording pencil or pen inscribes a continuous graph This graph is both a *time* and a *water-level change record* for the period over which the instrument was in continuous operation

Since these recorders require complete protection and since the most satisfactory record is secured when the float operates in a *still well*, they are usually installed in some kind of gage house which combines a still well with a superimposed platform on which the recording mechanism of the instrument is permanently supported A still well is a device for minimizing the effect of waves It consists essentially of some kind of a well, whose depth extends below all possible surface levels for the lake or stream to be measured and which is connected by a pipe of small diameter to the open water Plans for a gage house may be secured from the office of the U S Geological Survey.

Hook Gage

The essential feature of all types of hook gages is a recurved metal hook so set in one end of a staff that its free pointed tip is directed toward the opposite end When used, the hook-bearing end of the staff is submerged in the water, then the staff is carefully raised until the free end of the hook just pierces the water surface. The distance from the tip of the hook to some superimposed bench mark is then read on the staff. The virtue of the recurved hook lies in the fact that under ordinary circumstances it is easy for the observer, operating the gage from above the water surface, to detect the level at which the ascending end of the hook just breaks the surface film

For precise work there are hook gages on the market, equipped with verniers and slow-motion screws Such a gage may be fastened permanently to some support located in an operating position With such instruments, readings to 0 001 foot may be made, assuming that the conditions under which the instrument is used are favorable enough to warrant a record of that precision A still well or some similar device for minimizing surface disturbance is necessary for very precise measurements.

For many limnological purposes a satisfactory hook gage may be constructed as follows select a staff composed of some light, well-seasoned wood, about ⅜ × 1 0 in in transverse dimensions, and with length suitable to the task Construct a U-shaped hook from ⅛-in metal rod and fasten one end firmly into the lower end of staff. Round off free end of

hook to form blunt point, make free end of hook correspond exactly in level with lower end of staff. With zero point at lower end, graduate staff carefully by marking position of each foot of distance and further subdivide each interval into divisions of 0.1 foot. Cover with several coats of shellac. Choose favorable and convenient place for water-level measurements, provide some sturdy, immovable support, fasten to support and in vertical position a guide made of two 0.5×2-in. pieces of wood, straight, planed, and about 2 to 3 ft long, nailed together at edges to form L-shaped trough. From adjacent bench mark extend some known level to wooden guide, establish this level on guide by permanent transverse mark and label with elevation value at that point. When ready for use, place hook staff in inner angle of vertical guide, slide staff down until hook on staff is completely submerged, raise staff until free end of hook just pierces surface of water. Read distance from water surface to bench mark, using accurate, finely graduated hand ruler if necessary to secure more precise reading. Record distance as taken if bench mark has only an assumed value, if bench mark represents actual elevation above sea level, subtract water surface-to-bench mark distance from bench-mark value and the difference will be actual elevation of water surface at that time.

The hook gage just described operates more accurately in a still well or under some other circumstance in which wave action is reduced to a minimum. If it must be used in the presence of wave action, the reading should be taken by lowering the hook until its free end is as nearly midway between the trough and the crest of the waves as can be estimated. Obviously, such readings are less exact than those made on still water. On still water and with care, it is possible to measure water level with the kind of gage just described to a precision of 0.05 inch.

The supporting device must be protected against disturbance after it has been installed and the bench mark has been evaluated. Such a bench mark should be checked from time to time in order to discover if changes have occurred.

For some purposes a Stevens anchor gage may be convenient. It is essentially a hook with two balanced recurved points mounted opposite each other in such a way that the whole device resembles an anchor. It is usually operated on a steel tape wound on a small hand lift. When used in a still well, levels can be read with rather high precision by means of an overhead light which is reflected from the water surface on which the dimples made by the two points are readily seen.

Staff Gage

For ordinary and less precise purposes, the height of the water surface may be measured by a *staff gage*. Such a device consists of a graduated board established in a vertical position at a suitable, convenient place on the

side of a still well, retaining wall, dock, boat slip, breakwater, pile, stake, or similar structure It is so placed that the lower end is always below the minimum water level Such a staff gage may be constructed in any form and size suitable to the circumstances under which it is to be used For large lakes and streams such a gage should be made of some well-selected board, about 6 in. in width, 1 in thick, and with a length which exceeds the known variation in water level. It should be painted white with graduations marked with black paint at intervals of 1 ft and tenths of a foot. The 1-ft. intervals should be numbered in some convenient sequence Metal staff gages, covered with porcelain enamel and graduated in various systems, are now manufactured by certain supply companies, and for many purposes are superior

Water-streak Gage

For running waters, surface level may be determined as follows in the lower end of a 6–10-lb sounding lead, install a peg about the size of an ordinary lead pencil and about 4 in long, taper the free end of the peg to a rounded blunt point, attach the lead to a graduated rope or tape, suspend the sounding lead from some fixed overhanging support, on which is established a bench mark or a reference mark, and lower until the free end of the peg just touches the moving water, making a water streak The distance from the bench mark to the free end of the peg subtracted from the bench-mark value gives actual surface elevation If the reference mark is an arbitrary one, the reading provides a relative value. This method lacks the precision of certain others but for many purposes it is useful

Other Methods

If reduced light conditions, distance of water surface from eye of observer, or any other circumstance makes it impossible to see the dimples made by a hook gage or by an anchor gage, the water level may be determined by the use of an inelastic tape or line long enough to reach from the reference or bench mark to the water surface Attach a weight at the lower end of the line and smear the lower two feet of the line with carpenter's blue chalk Lower the line until the weight and part of the lower chalked section of the line is submerged. Mark line at top to correspond with reference mark and raise line. The water line will show on the blue chalk Measure distance between wet mark on chalk and the upper reference mark and make any further computations necessary to determine the water level.

Certain pastes are available on the market which, when smeared as a coating on a rod or tape, markedly change color when brought into contact with water, producing a sharp line at the water surface.

Selected References

(For Chapter 4)

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MAP CONSTRUCTION

Equipment and Materials

The following easily obtainable items of equipment and materials should be provided:

1 Drawing Table Substantial, smooth-surface table so located that the operator can work all around it. Size not less than 3 × 3 ft., preferably larger.

2 Meter Sticks. Two or more good quality, wooden meter sticks. They must be *straight* in all positions, should be used only for map construction work, and should be stored, when not in use, on a flat, straight surface and kept dry.

3 Rulers. Good quality 1-ft. rulers; straight.

4. Triangles Two or three sizes, celluloid type is preferable.

5. Parallel-line Rulers. Not absolutely necessary but very convenient.

6. Paper. Some good grade, light-colored paper having a surface which will withstand reasonable erasures without serious damage, heavy enough to rest flat on board.

7. Protractors. Large circular or semicircular protractors, 12–14 in in diameter and graduated to ¼ degree, paper, celluloid, or metal. More elaborate protractors can be secured but for purposes described herein are seldom necessary Smaller protractors should be avoided Celluloid protractors have the advantage of being translucent

checking accuracy of protractors. Protractors may be in error either because of imperfect construction or lack of adjustment, the latter being a possible fault in three-arm protractors. Some types of protractors can not be readjusted but must be tested for significant error. Metal test plates, made especially for this purpose, afford a convenient and quick means for checking If such a test plate is not available, a test *pattern* can be constructed as follows Across the center of a large sheet of heavy paper draw two straight lines *exactly perpendicular* to each other These two lines must be set up with the greatest care possible. Extend lines to edges of paper Bisect the right angle in each quadrant and extend straight line through bisection point and the central intersection of all lines Superimpose protractor over this figure, make the central point of both protractor and test figure coincide; rotate protractor in a series of positions and determine the amount of agreement in each instance

8 OTHER EQUIPMENT Erasers of several kinds including block of art gum, Scotch cellulose tape, good T square For further information and directions relating to drawing tools and materials, consult some standard work on cartography.

CONSTRUCTION OF HYDROGRAPHIC MAP

Irrespective of the method used in making soundings in the field, the map should be constructed as follows

1. Enter all numbers representing soundings in the normal reading position, i e , so that all numerals are in the same position and readable when bottom of map is nearest reader

2 Use simple, clean-cut, open style of numeral to represent soundings, lightface italic style is recommended.

3 Use numeral of easily readable size, numerals whose maximum height is 2–3 mm. are recommended.

4. Place numeral on map so that it is centered on the sounding position.

5 Draw submerged contours at desired intervals Construct such contours by drawing a continuous line connecting all points having same depth; pass contour line through all numbers having exactly the value of the chosen contour, where the exact chosen value is absent pass contour line between those soundings which are less and greater than the chosen value, estimating position of contour line between the two values.

6. Make all contour lines of uniform thickness; use line distinctly lighter than shore line

7. Remove all construction lines not necessary to future interpretation of map

8 On every hydrographic map, when finished, there should appear certain essential information and explanations. Maps will differ somewhat in these requirements depending upon their nature and detail. However, most or all of the following items should appear on every map

a. General title, if map is one of a series
b Series number, if map is one of a series
c. Official name of lake or lakes, stream or streams
d. Geographic location (state, county, township, section)
e. Scale, or scales
f. Compass figure
g. Low-water datum and its use
h Date of field work
i. Date of map construction
j. Names of field party
k Names of draftsmen
l. Abbreviations used and their meanings
m. Key to symbols used

n Units used in soundings (feet, meters, fathoms)
o Methods used in field work
p Distance between guide lines, if guide lines are drawn
q Value of submerged contours

Still other information may be included if circumstances warrant

9 Since water-surface elevations fluctuate, causing depths to have a different value in the same place at different times, soundings should be referred to some known elevation. It is a standard practice to reduce soundings to *low-water datum* for that body of water This low-water datum may be the lowest known surface elevation for that body of water, or it may be an assumed one, preferably the former if a sufficient number of records are available To reduce all soundings to low-water datum, it is necessary to know the surface elevation at the time the soundings are made, then the difference between the low-water datum and the surface elevation is subtracted from the sounding as made in the field, and the value so reduced is entered upon the map It must then be remembered that on any hydrographic map in which all soundings are reduced to low water datum, depths on the map are minimal depths to which must be added some value in order to determine the true depth at a certain position on any particular date

Map Colors

Colors are often useful in portraying on a map certain kinds of physical features of lakes or streams The following ones are commonly used

1 For depths of water
   a Blue, deep shade—very shallow water
   b Blue, light shade—deeper shallow water
   c White—deep water

2 For finely divided bottom materials
   Yellow—sand
   Blue—fibrous peat
   Tan—pulpy peat
   Brown—muck
   Dark gray—marl

Application of Colors on Maps

It is often desirable to represent certain limnological features on maps by the use of colors There are various ways of applying colors to maps, some of which are both simple and effective

Colors from Wax Pencils These colors may be applied permanently

by the following simple method Secure a supply of a good grade of colored wax pencils, such as "Venus" or "Dixon" brands, representing the desired colors, with rapid pencil strokes fill in roughly the area to be covered, then by means of a blunt-pointed paper pencil (composed of closely and spirally wound paper) dipped in benzine, redistribute the color into a uniform tint by rubbing it evenly Under this treatment the color can be spread with satisfactory results When the benzine evaporates the color is permanent; it does not rub off or smudge Results are usually acceptable when the coloring is done on any paper of fair quality and appropriate color, provided the application has been done with reasonable care If such coloring is done on waterproof paper the product is likely to have some superiority.

Somewhat similar, but perhaps less satisfactory, results may be secured by the use of any ordinary good grade, colored crayon or pencil followed by smoothing accomplished by rubbing the penciled surface with a bit of cloth soaked in good grade gasoline. For finer work the cloth should be wrapped around the end of a toothpick or the blunt end of a wooden penholder; for work on larger areas the cloth can be bunched into a soft mass. However, much depends upon the kind of crayon or pencil used and the operator must make a series of preliminary tests in order to arrive at a satisfactory selection.

An even tint may be brushed onto maps by means of ordinary water colors applied with a fine sable brush Water colors adhere well to paper and do not spread. Powdered aniline dyes when dissolved and applied with a brush are likewise serviceable for producing tints on maps. Also, some use may be made of waterproof colored inks applied with a brush. However, the satisfactory application of water colors, aniline dyes, or colored inks requires more time, patience and skill than does the wax pencil-benzine method described above and often produces no better, or even inferior, results. These colors must be painted onto the surface of the paper, and if an even tint is to be secured, speed and accuracy are required In painting on colors, the back of the map should be elevated somewhat so that the paper is tilted downward toward the operator If a considerable area of surface is to be colored it should be subdivided into portions of convenient size Each subarea should be painted separately and a white line left between adjacent subareas. This white line is filled in later with a half-dry brush, a procedure which gives a much better result than overlapping the painted edges Painting a surface should proceed *downward* and the advancing front of the colored materials must not be allowed to dry during the progress of the work. Since it is very difficult to improve faulty or uneven painting, every care must be taken to apply the color in the best way possible. Areas too heavily colored may be lightened somewhat by the judicious use of an eraser, and those which are too light can be dark-

ened with a half-dry brush, but there are limitations to these remedial measures.

Descriptive Terms and Their Abbreviations

No set of descriptive terms has been adopted as standard for designating those various physical features often important in the analysis and mapping of lakes and streams The following lists are offered as a suggestion of how such terms and their abbreviations may be assembled. Abbreviations may be entered upon a map in such a way that location and extent of the features concerned are indicated in a useful pictorial fashion. These lists may be modified, altered, and extended to meet special needs Suggestions given on pp 72–75 for the proper use of symbols on maps also apply to the use of descriptive abbreviations

BOTTOM MATERIALS

bedrock	– *br*	miscellaneous debris	– *md*
boulders	– *b*	mud	– *m*
coarse gravel	– *cg*	muck	– *mk*
false bottom	– *fb*	peat	– *p*
fine gravel	– *fg*	rubble	– *r*
hardpan	– *hp*	sand	– *s*
intermixtures	– *im*	silt	– *st*
marl	– *ml*		

CHARACTERS OF BANK

boggy	– *bg*	low	– *l*
cliffs	– *c*	medium height	– *mh*
cultivated	– *cv*	marshy	– *ms*
depositing	– *dp*	rock outcrop	– *ro*
eroding	– *er*	shrubs	– *sh*
flood level	– *fl*	swampy	– *sw*
high abrupt	– *ha*	topsoil	– *ts*
high sloping	– *hs*	wooded	– *w*

Also other descriptive terms and abbreviations from list on bottom materials

INFLOWING WATER

boggy	– *by*	surface runoff	– *sr*
clear	– *cl*	small volume	– *sv*
large volume	– *lv*	turbid	– *tr*
springs	– *sp*		

NATURE OF FLOWAGE OF STREAMS

eddies	– *ed*	rapid	– *rp*
falls	– *f*	smooth flow	– *sm*
pool	– *p*	turbulent	– *tb*
riffle	– *rf*		

SHADING

dense	– *ds*	open	– *o*
partly shaded	– *ps*		

SYMBOLS

Much detailed information can be incorporated on maps by means of symbols. Various systems may be devised for special purposes provided that the design of none of the characters used duplicates that of other symbols. No standard code of symbols devised for limnological purposes has been adopted. Among the suggested ones which follow are a few standard topographic symbols used by certain branches of the Federal government, others have been selected from various sources, and many of the biological ones are proposed by the writer.

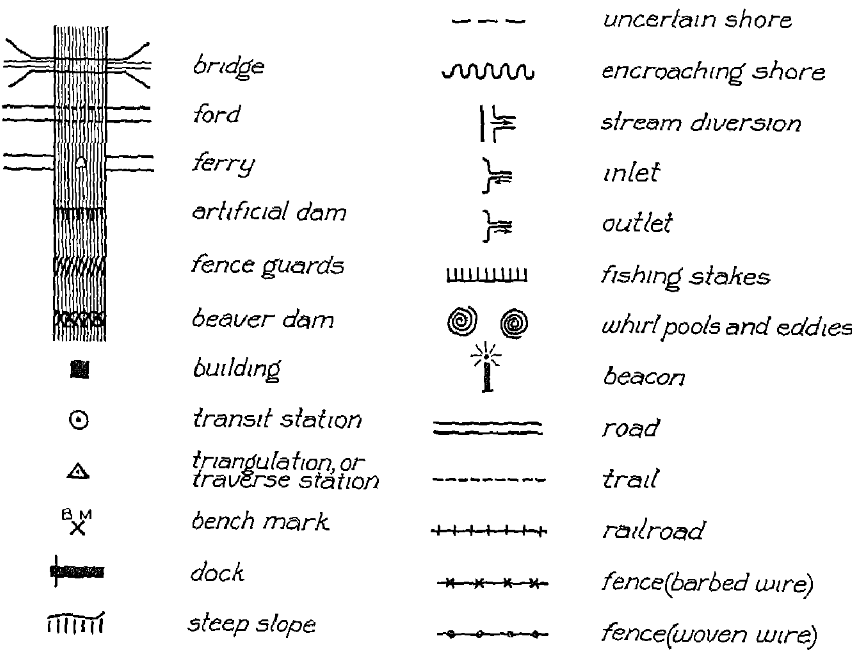


FIG. 14. Symbols for physical features

In the use of symbols on maps, the following suggestions should be considered

a Use symbols no more generously than is necessary Undue use causes congestion in that area of the map and tends to obscure its major features

b. Make symbols no larger than clear legibility demands Their size should be in keeping with the size of the map as a whole

c Symbols should be so constructed on the map that they are background rather than foreground characters

d When uniformity of an area is to be indicated by repeating its symbol over the space concerned, keep the distribution of the repeated symbol as thin as possible without sacrificing the result intended

e In so far as is practicable, put all symbols on the map in the vertical position Maps with symbols turned upside-down and at various angles are difficult to use.

f. Symbols should not be entered upon a map until all of its major features have been completed

g The design of a symbol should be as simple and as distinctive as possible Avoid ornate patterns

h Union of symbols to represent a combination of two or more meanings should be done with great discretion, ordinarily it should be avoided

i Incorporation of many different kinds of symbols into the same map or area should be avoided since it may render the map more or less unintelligible It is much preferable to divide the various sets of symbols among two or more duplicate outlines of the same map

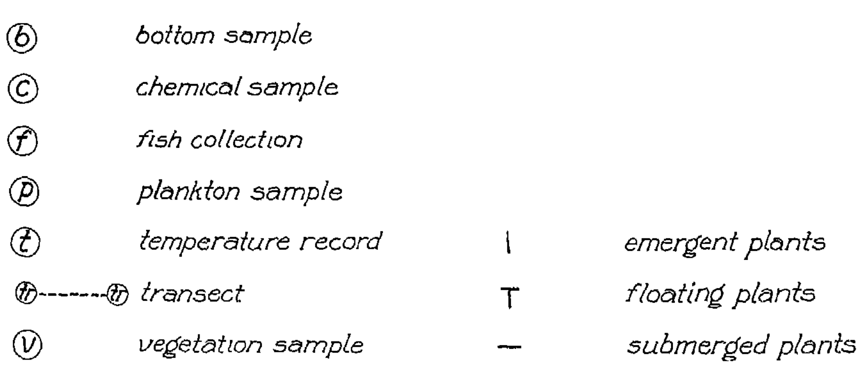


FIG 15 (*Left*) Symbols representing sampling stations

FIG 16 (*Right*) General symbols representing vegetation Used when rough division of aquatic vegetation into *emergent*, *floating*, and *submerged* classes is adequate.

DUPLICATING SYMBOLS ON MAPS

If symbols are to appear scantily on a map they may be entered upon the areas involved by rapid freehand sketching with pen. However, many limnological maps require numerous repetitions of various symbols in order to produce the necessary distribution record Under these circumstances freehand sketching is too slow and tedious to be practicable. A relatively simple but effective solution to the problem of duplicating symbols can be found in the use of rubber stamps constructed as follows To the end of a cylindrical handle of convenient size and length seal a block of rubber having a density about that of an ordinary lead-pencil eraser. On the free end of the rubber block, sketch with pencil, in the form and size desired, the symbol to be used taking particular care to make the margins of the figure very definite and regular Turn into a vertical position and fasten the handle in a vise, with the rubber block uppermost Install over the rubber block and in working position a large-diameter magnifying glass Using a very sharp, fine-pointed scalpel, excavate to a lower level all rubber surface not included in figure of symbol, taking particular care to keep the margins of the figure smooth and regular Remove pencil marks from the figure of the symbol which now stands in relief Press stamp, so made, on an ink pad and make trial impressions on paper to determine whether further work on the stamp is necessary to produce an acceptable result Judicious smoothing of cut edges may improve the impression When in satisfactory form, a stamp of this type makes it possible to repeat the symbol many times on a map when such repetition is required

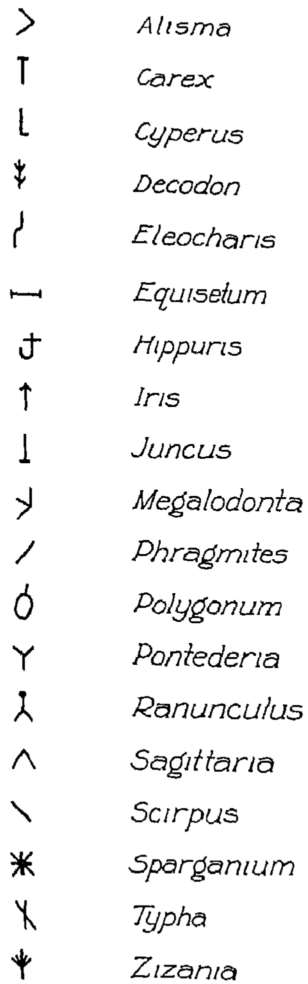


FIG 17 Symbols representing *emergent* aquatic plants Assembled from various sources

Since duplicator and ink-pad inks usually fade, care should be taken to use a pad saturated with an ink which is permanent and which provides the desired color Various modifications of this simple method of making

stamps can be devised If preferable, the sketches of symbols may be sent to a manufacturer of rubber stamps Such commercially made stamps are likely to yield impressions superior to those of the homemade variety.

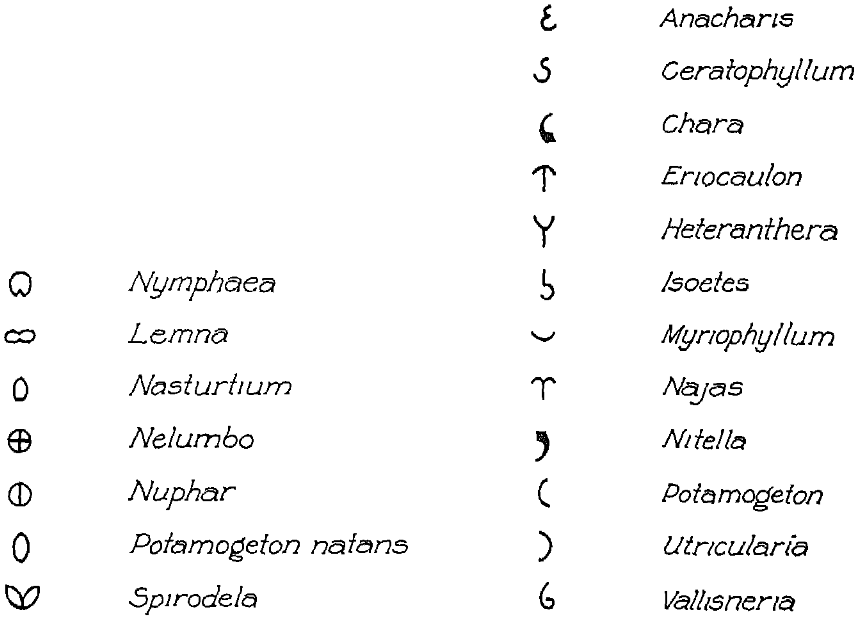


FIG 18 (*Left*) Symbols representing *floating* aquatic plants. A selected series of common genera Assembled from various sources

FIG 19. (*Right*) Symbols representing *submerged* aquatic plants. A selected series of common genera. Assembled from various sources

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MORPHOMETRY

That branch of limnology which deals with the measurement of morphological features of the basin of a lake or stream and its included water mass is known as *morphometry* Certain fundamental conditions of biological productivity arise directly from the structural relations of inland waters Therefore it is necessary for the limnologist to make various measurements of morphological features of lakes and streams in order to determine the role which they play in limnological phenomena

In order that morphometric data may be of value, measurements must be based upon reliable hydrographic maps of appropriate size and construction Other things being the same, the larger the map the more accurate the results It is futile to try to use diminutive maps Small maps, if otherwise suitable, may be enlarged (1) directly by some photographic process, (2) traced from a lantern slide projected on a screen; or (3) by means of a pantograph Other forms of enlargement may also be used if preferred However, care must be taken that certain limitations inherent in small maps are not accentuated in enlargements

LAKES

MAXIMUM LENGTH

Length of line connecting two most remote extremities of lake.

The form and position of this line must be such that it represents as correctly as possible the true open-water length. This line may be straight, as in lakes of regular, ovoid form, but often must be curved in form, as in instances of ox-bow lakes or other lakes with irregular shape. Such a line should not cross any land other than islands

Measurements of maximum length of irregularly shaped lakes based upon a straight line connecting the most remote extremities and crossing portions of the mainland have little or no limnological value and should be avoided. Some lakes are of such shape that it is difficult to select one position for a maximum length measurement, also in others, as for example, lakes of a stellate form, there may not be a definite, single, maximum-length axis. In all such instances, the method and position of measurements should be definitely specified in descriptions

MAXIMUM EFFECTIVE LENGTH

Length of *straight* line connecting most remote extremities of lake along which wind and wave action occur without any kind of land interruption

Maximum total length and maximum effective length may be, and often are, identical. However, when islands or groups of islands are so located that they effectively interrupt the continuity of wave action and virtually divide the lake into two or more portions, maximum total length and maximum effective length are different.

MAXIMUM WIDTH

Length of straight line connecting most remote transverse extremities and crossing no land other than islands; line approximately at right angles to maximum-length axis

MAXIMUM EFFECTIVE WIDTH

Length of straight line connecting most remote transverse extremities of lake along which wind and wave action occur without any kind of land interruption

MEAN WIDTH

Area of lake divided by its maximum length.

MAXIMUM DEPTH

Maximum depth known for lake expressed in feet, meters, or fathoms

MEAN DEPTH

Volume of lake divided by its surface area

MEAN DEPTH-MAXIMUM DEPTH RELATION

Mean depth divided by maximum depth. Expressed as a decimal value, it serves as an index figure which indicates in general the character of the approach of basin shape to conical forms.

MAXIMUM DEPTH-SURFACE RELATION

Maximum depth divided by the square root of the surface Expressed as a decimal value, it is an indication of the relation of depth to horizontal extent

DIRECTION OF MAJOR AXES

Expressed in general compass directions, as for example, NE–SW, or NNE–SSW

AREA

Only in occasional instances is it feasible to determine the area of a body of water by direct measurements in the field. Consequently, methods for measuring area usually require a map of suitable scale and accuracy.

Planimeter Method

This method depends upon the use of a well-known instrument called a planimeter. It is specially designed for measuring the area of a plane surface regardless of the shape of its outline. It is the most rapid and, when carefully operated, the most accurate means of determining areas. Planimeters are made in many forms, some of which are costly. The simple polar planimeters (Fig. 20) are modest in price and meet many of the needs of the limnologist. Manufacturers usually supply detailed instructions for the operation of their instruments. The following description relates to the use of one of the simple polar planimeters.

EQUIPMENT. Polar planimeter, reading glass or hand lens; map of suitable character and scale, Scotch cellulose tape, or some similar adhesive.

CORRECTIONS AND ADJUSTMENTS. If the planimeter has an adjustable tracer arm, the instrument must be set properly for the desired unit of measurement. In planimeters having fixed arms, the value of the unit of measure is determined by the manufacturer and cannot be changed.

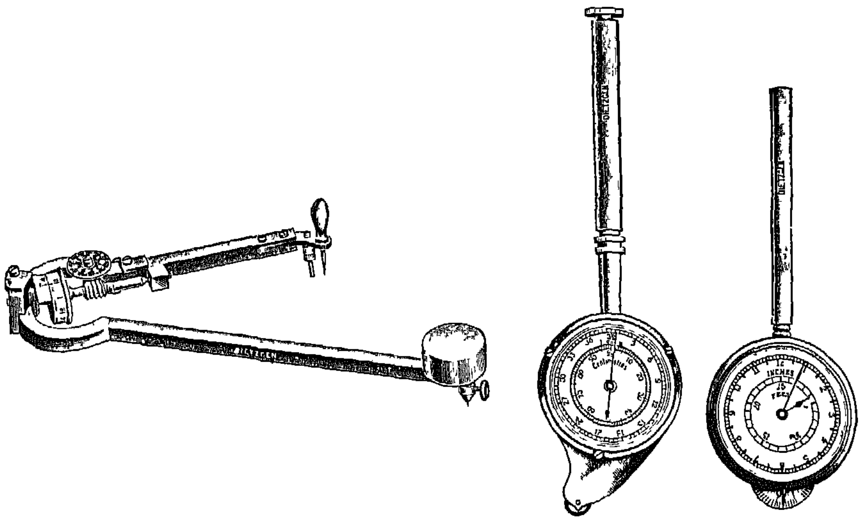


FIG. 20. (*Left*) A simple type of polar planimeter. (*Right*) Two types of map measurer, one at right with graduated tracing wheel. (Courtesy, Eugene Dietzgen Co., Chicago, Ill.)

Test the accuracy of the planimeter by one of the following methods:

1. The simplest and most reliable method of testing the setting and the accuracy of a planimeter is by the use of a *trial disk* sometimes furnished by the makers. It is a round metal disk whose grooved rim surrounds a known area and around which the tracer point can travel in a groove with exactitude. Remove glider if present, set planimeter in the proper way, trace the area on the trial disk, compare reading on planimeter with known area of the disk. Or if preferred, make several continuous nonstop tracings around the plate and divide the total reading on instrument by the number of circuits around the plate, then compare average reading on planimeter with known value of plate If discrepancies occur they must be due to (a) wrong adjustment of planimeter arm, (b) to bad condition of planimeter, or (c) to error in reading planimeter.

2 Another mechanical method of checking a planimeter is by the use of a planimeter *testing rule* which consists of a graduated metal strip of convenient dimensions anchored at one end but free to rotate about a pivot At known distances from the center of the pivot there are small holes. Remove glider if present, set planimeter in proper way, making sure that the free end of the testing rule can rotate completely without making contact with any part of the planimeter. Set tracer needle of planimeter in hole in free end of testing ruler, mark with pin point the exact starting position of free end of rule, set planimeter scales in initial reading positions, swing tracing needle throughout full circle determined by testing rule, returning exactly to starting point (or make several circuits and compute average). Using distance from pivot to tracing-point hole as radius of circle described by tracing point, compute area of circle, check computed value with area read on planimeter.

3. With pair of dividers draw on suitable surface a circle of known diameter, make circle as large as possible within operating distance of one setting of planimeter, compute area of circle so constructed. Measure area of circle three times with planimeter, use average of three readings and convert reading to same units as computed value, compare computed and measured values of area.

Procedure

1. Spread map to be measured as smoothly as possible on firm, flat horizontal support, preferably a drawing table; fasten map securely to table with Scotch cellulose tape, gummed tape, or some other suitable means

2 If map is too large to be measured by one set-up of planimeter, rule on map a series of equally spaced horizontal and vertical lines thus dividing area of map into sections, make such subdivisions as large as can be conveniently covered by planimeter.

3. Select an apparently suitable position *outside* of area to be measured and set needle point (fixed point, or fulcrum) into paper; make trial swing-around over area with tracer point to determine if all parts of periphery can be reached, if not, another set-up must be sought

4 With suitable set-up position determined and instrument properly balanced, place tracer point on outline of area, make slight indentation or mark on paper to indicate starting point and set tracer point on it, with needle point and tracer point carefully kept in position, lift wheel from paper and set all graduated scales at zero, lower wheel to rest on paper, check setting of instrument, and make further adjustments if necessary.

5. Make tracer point follow, gently and as accurately as possible, outline of figure to be measured, proceeding in a *clockwise direction* and returning to starting point. When tracer point reaches starting position, read and record planimeter values, reread for check.

6 Repeat tracing of outline at least twice, resetting instrument each time at initial starting point, and divide sum of all readings by number of tracings of figure. Or if preferred, make at least three continuous, nonstop tracings of figure and divide total reading of instrument by number of circuits around figure.

7. If size of map requires that it be measured in sections, repeat operations described above for each section and add average readings of all sections.

8 By use of scale on which map is constructed, draw on paper a square which will contain exactly one unit of area (for example, 1 sq. mi) in which final results are to be expressed Carefully measure this square with planimeter and determine number of planimeter units in square representing one actual unit of area of lake Compute area of square by use of dimensions and use value as check on planimeter reading Divide total number of planimeter units in whole lake by number of planimeter units in square and result will be area of lake in terms of unit used (square mile, hectare, square rod).

General Considerations

a. While potentially the planimeter method is the most exact of the various methods for determining area, the personal error in instrument operation may be considerable if the operator is inexperienced Preliminary practice is always desirable and for the beginner it is imperative if results are to be dependable.

b It is possible to operate a planimeter with the needle point (fixed point, fulcrum) *inside* of the figure to be measured and the detailed instructions supplied by dealers usually describe the necessary procedure. However, the inside position for the needle point is usually not recom-

mended since the method is complicated and the results obtained are generally not as accurate as those obtained by the outside position

Hatchet-planimeter Method

A hatchet planimeter, sometimes called a "jack-knife planimeter" or a "Prytz planimeter," is an exceedingly simple device which when properly constructed and operated will measure the area of a plane figure, either regular or irregular in outline, with an accuracy close to that of an ordinary polar planimeter

CONSTRUCTION A hatchet planimeter (Fig 21) consists of a metal rod bent at right angles at the ends, forming a long arm *a* and two short legs One leg is tapered to a smooth tracing point *tp*, the free end of the other leg is ground or flattened into a sharp blade *b* Any good grade metal rod, about 4 mm in diameter, will serve Some rods can be bent in a vise without preliminary treatment; others, particularly steel, should be heated to a dull red just prior to bending The main arm *a* may be any convenient length but there will probably be few occasions for constructing an in-

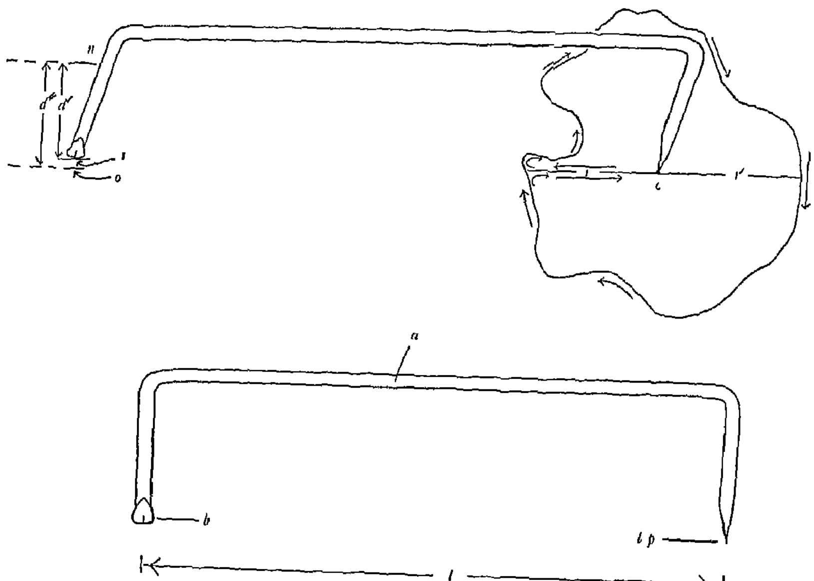


FIG 21 Hatchet planimeter. Lower figure shows construction of instrument. Upper figure shows method of use (*a*) Arm (*b*) Blade (*c*) Center of gravity of figure (*d'*) Distance *i* to *n* (*d''*) Distance *o* to *n* (*i*) Original blade position (*l*) Distance from center of tip of tracer point to end of mid-axis of blade leg (*n*) Terminal position of blade at end of first measurement (*o*) Terminal position of blade at end of second measurement (*r*) Line from center of gravity of figure to perimeter (*r'*) Line from center of gravity to perimeter, opposite line *r*. (*tp*) Tracing point

strument less than 25 cm. long. Longer ones are useful in the measurement of large surfaces. The legs should be about 7 cm. long. Certain critical points of construction must be observed, namely (1) The rod must be straight, rigid and heavy enough to insure that the blade will maintain continuous contact with the paper when the tracer point *tp* is in motion (2) The long axis of the blade, when extended, must pass through the tip of the tracer point *tp*. (3) The edge of the blade must be kept razor sharp (4) Each end of the edge of the blade must be smoothly rounded upward to insure free passage over the paper

Procedure

1. Cover smooth flat table with large sheet of *unglazed* paper, attach edges to supporting surface with Scotch cellulose tape or other similar adhesive, place map or figure to be measured on top of unglazed paper in a convenient position and immobilize it with adhesive.

2 Locate approximately the center of gravity of map or figure (Fig. 21, *c*), erect line *r* from center *c* to any selected point on periphery of figure.

3. Place tracer point *tp* on center of gravity *c*, holding planimeter so that legs are vertical and blade is at some convenient position, mark initial position of blade *i* by pressing edge slightly into paper, producing an indentation, mark indentation and label it

4. Hold tracer leg of instrument lightly but steadily between thumb and first two or three fingers, using tip of little finger as glider support, hold instrument so that legs are vertical, do not allow instrument to tilt at any time during a measurement.

5. Make tracer point traverse line *r* from center of gravity *c* to perimeter of figure; then trace perimeter clockwise as shown by arrows in Fig. 21, returning to center of gravity *c* along line *r*; mark new position of blade by pressing edge slightly into paper and label it *n*.

6 Measure carefully distance *d* between original blade position *i* and terminal one *n*, check this distance by one or both of following methods. (1) With blade exactly at *n* and tracer point at *c*, retrace figure as outlined in paragraph 5 above but in counterclockwise direction; if blade returns exactly to *i*, which it rarely will do, tracing has been duplicated exactly and presumably distance *i* to *n* is as correct as conditions of test will permit, if new blade position occurs near, but not on, initial position *i*, make impression in paper by pressing blade into it, mark and label *o*, then distance sought *d* is derived from formula $\frac{d' + d''}{2}$ in which d' is distance *i* to *n*, and d'' is distance *o* to *n*. Repeat operations in case of doubt (2) Repeat independently, three or more times, the operations

indicated in paragraphs 3–5 given above, each time shifting figure being measured so that blade of planimeter will make its tracings on new areas of paper; use average of all measurements of distance *i* to *n*

7 Measure carefully distance from center of tip of tracer point to that point of blade which coincides with end of mid-axis of blade leg (Fig. 21, *l*).

8. Calculation.

Area of figure traced is computed by formula, $a = d \times l$, in which *a* is area desired, *d* is distance between initial *i* and final *n* or average position of blade, and *l* is distance between tip of tracer leg and middle of blade, expressed in same linear units as *d*

Inherent Errors. When distance *d* in the formula given above is small as compared with the length *l* and when the planimeter has been operated under the best of conditions, the instrument measures area directly without significant error, if, on the other hand, the distance *d* is large, serious error appears. This error becomes greater as the size of *d* increases If the greatest dimension of the area to be measured is less than one-half the length (*l*) of the instrument, the inherent error is negligible, but if *d* exceeds one-half of *l*, the figure must be subdivided and the parts measured separately Consequently, the longer the planimeter the larger the area which can be measured within one tracing without requiring the application of correction values or subdivision of the figure

If this instrument is used to measure the area of undivided figures the dimensions of which exceed the limit indicated above, then it will be necessary to construct a table of corrections as follows Either draw a series of conventional figures (triangles, squares, parallelograms, circles, the areas of which are easily computed mathematically) in graded sizes from small to large, or use cross-section paper Following procedures outlined in paragraphs 3–8, carefully make measurements of a graded series of areas, compare computed values with corresponding ones secured with the planimeter and determine corrections necessary to make the planimeter readings accurate

Errors of Operation. The operator should practice on regular figures of known areas until some skill in use of the instrument is acquired. Important precautions against errors of operation are (1) In tracing a figure the tracer point must be so handled that the blade describes its various courses without any interference The tracer leg must turn freely between the thumb and fingers (2) In all operations the blade must be kept on *unglazed* paper (3) The blade must operate over a uniform, uninterrupted surface, imperfections in the paper, edges of paper, and other deviations from uniformity lead to error. (4) At all times during a tracing, the tracer leg must be kept in a vertical position. (5) The sharper the blade the better the results, a dull blade must be avoided (6) The rod must be

of such weight that the blade is held continuously on the paper, however, overweight should be avoided.

General Considerations

a. The successive terminal positions of the blade (*i*, *n*, *o*,) fall on the arc of a circle the radius of which is the length *l*, and distance *d* (*i* to *n*; *n* to *o*, etc.) should be measured along this arc However, measurement along the chord is much simpler and if distance *d* is relatively small the error is negligible, but as *d* increases the error becomes greater and corrections are required.

b. In regular figures (circle, square, triangle, etc) the center of gravity *c* is easily determined by well-known methods, but in irregular ones the location of this point is difficult and often must be arrived at by approximation. Fortunately the precise location of this point is not necessary and small departures from it do not result in significant errors. Only when this starting point is taken some distance from the true center of gravity does the error become consequential

c. If it is not possible to locate with certainty the center of gravity, a test may be made as follows Measure the area of the figure with the planimeter arm extending to the left using *r* as the going and returning line, then without changing the position of the figure, repeat the measurement with planimeter arm extending to the *right*, using *r′* as the new going and returning line, compare results obtained. Essentially the same result is obtained by turning the paper bearing the figure through 180° and repeating the tracing with the planimeter still on the same side

Weight Method

The weight method is based upon the fact that if a carefully cut-out paper model of a map is weighed on a balance of suitable sensitivity and if a unit area (e.g., 1 sq. mi) is cut from the same kind of paper according to the scale of the map and then weighed, the area of the body of water is obtained when the weight of the whole model is divided by the weight of the unit area. If the proper conditions and safeguards are observed this method yields satisfactory results.

EQUIPMENT Map of suitable character and scale, balance having sensitivity commensurate with quantity and thickness of paper used, ordinary laboratory scalpel with sharp point and rounded edge, and paper of suitable weight and uniformity on which to copy map

CORRECTIONS AND ADJUSTMENTS Many grades of paper used in map making, map printing, or map copying are sufficiently uniform in thickness and weight to make it certain that the differences in weight of various areas within a sample of the paper fall within the other errors and limi-

tations of the method. However, in case of doubt, or when unusual materials are considered for this purpose, test for weight uniformity as follows fold a large sheet several times in such a way that by one operation several pieces of *equal size* can be cut out simultaneously from various areas on the sheet, make the cut pieces as large as circumstances will permit, weigh each piece separately on a balance sensitive enough to make weight comparisons of the individual pieces significant Repeat on at least two other large sheets from same stock If variations occur which seem to exceed the general error of the method, discard the proposed material and try another.

Procedure

1. If duplicate copies of map are available and if map is printed on paper suitable for weight method, cut model directly from printed copy However, if model cannot be cut from printed map, transfer outline to another sheet of acceptable paper by any one of several convenient ways, such as carbon copy or direct copying by transmitted light.

2 Fasten map, or copy of map, on large piece of smooth beaverboard or some other similar material against which cutting may be done; with sharp scalpel held vertically between thumb and first finger, make a continuous series of close, vertical thrusts through the paper, cutting through the middle of the line representing shore line, continue until entire shore line is thus treated

3 Remove model from surrounding paper, with sharp scissors, trim edge of model carefully, removing all tag ends and irregularities due to cutting, especially those between scalpel thrusts. Weigh model of map

4. In similar manner, cut from same sheet of paper one unit area (1 sq. mi., or some other desired unit area) as determined by scale of which map is drawn and weigh it.

5. Divide weight of model of lake by weight of model of unit area and quotient will be area expressed in unit used in unit area

General Considerations

a. Islands, if present, must be cut from the model before it is weighed

b If this method is employed in instructional work, the average weight of all of the models made by a class divided by the average weight of all of the unit areas will probably yield a more accurate value

c Both model and unit area should be preserved with the other original records of the work.

d A paper made in very uniform weight and designed especially for this purpose is sometimes obtainable

e Materials other than paper, e g , wax plates, may be used, provided they meet the necessary requirements of convenience and uniformity

Cross-section Paper Method

When the outline of a lake is superimposed upon cross-section paper (squared paper) its area can be measured by dividing the total number of squares included by the number of similar squares included within an area representing, according to the scale of the map, that unit in which it is desired to express the area.

EQUIPMENT Map of proper character and scale, sheets of suitable cross-section paper.

CORRECTIONS AND ADJUSTMENTS. Cross-section paper should be tested for uniformity of ruling before it is used. Check in both vertical and horizontal directions, also in several different areas on same sheet.

Procedure

1 By means of tracing table, carbon paper, pencil carboning on back side of map, or any other convenient method, transfer outline of shore line of map to cross-section paper. Retrace until outline is distinct at all places.

2 Count all squares *completely* within shore line of map; then *count as whole squares* those squares about the periphery of the map whose areas are *one-half or more* within the shore line, but ignore those that are less than one-half within the figure Assemble all counts into one total.

3. By means of scale on map, draw on same kind of cross-section paper a closed figure representing one unit of area, e g., square mile If drawn as a circle, count squares within this figure as indicated in the foregoing paragraph, expressing total in same size squares as that in total for whole lake area, if laid off in form of square, count all complete squares and estimate *all* incomplete squares. Divide total within entire map by total within unit figure and quotient will represent desired area expressed in units chosen

General Considerations

a Some system of marking squares as they are counted is necessary in order to avoid mistakes.

b Within practical limits, the smaller the squares on cross-section paper the smaller the error of the method

c Cross-section papers ruled in large squares which in turn are subdivided into smaller squares have a counting advantage over those ruled only in one size.

d The incomplete squares about the periphery may all be estimated as to the portion included within the figure, as for example, 0.5, 0.1, 0 9, etc., and the total of all incomplete squares thus computed Errors of estimation in the incomplete squares are likely to be compensating to

some extent since in a large number of estimates there tend to be about as many *underestimations* as there are *overestimations* However, estimating *all* incomplete squares is slow and laborious, and the end result is not likely to show any improvement over the method of counting as whole squares all those which are one-half or more within the figure and ignoring those less than one-half within the figure

e Counts of squares should be repeated for verification both on the map and on the unit area.

f With proper materials and with the necessary personal care, good results are obtainable with this method

Method of Geometrical Figures

This method consists of the division of a map, whose area is sought, into a series of geometrical figures (triangles, rectangles, and trapezoids) the area of which can be computed from the scale on which the map is drawn by the use of well-known mathematical formulas.

EQUIPMENT Map of suitable character and scale—within convenient limits, the larger the map the better, protractor, rulers with fine, correct graduation, dividers, triangles.

Procedure

1. On map to be measured, erect within shore line the largest rectangle, triangle or trapezoid which it will contain and compute its area

2 Divide remaining portions of area not so included into triangles and compute their areas. Continue until all of map has been covered.

3 Add areas of all geometrical figures. Using scale of map, determine area representing one actual field unit (i e., square mile) Divide total area of lake by that of unit area and quotient will be area of lake in terms of unit area selected

General Considerations

a This method is practicable only for bodies of water which have a very regular outline

b. When the lengths of three sides of a triangle, *a*, *b*, and *c*, are known in terms of the scale of the map, its area may be determined by use of the formula

$$Area = \sqrt{s\ (s-a)\ (s-b)\ (s-c)}$$

where $s = \dfrac{a + b + c}{2}$

Method of Ordinates by Simpson's Rule

EQUIPMENT Map of suitable character and scale, rulers, dividers, triangle

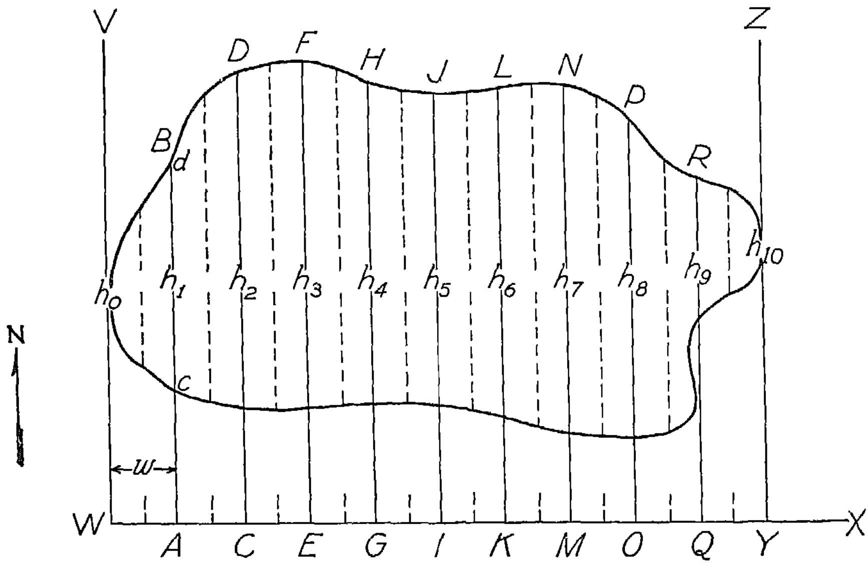


FIG 22. Diagram illustrating measurement of area by method of ordinates by Simpson's rule, also measurement of area by method of average ordinate rule

Procedure

1. As in Fig 22, draw line *WX* below map to be measured and in horizontal direction, draw vertical line *WV* tangent to left end of figure, draw vertical line *YZ* parallel to *WV* and tangent to right end of figure

2. Divide distance *WY* into an *even* number of *equal* parts and draw ordinates *AB*, *CD*, *EF*, and others Label left tangent ordinate h_0 and the others successively to right as h_1, h_2, h_3, etc , ending with right tangent.

3. Measure length of ordinate h_1 (*c* to *d*) within periphery of map and record it, measure and record all other ordinates in same fashion Substitute values in formula

$$Area = \frac{1}{3} w (h_0 + 4h_1 + 2h_2 + 4h_3 + 2h_4 + 4h_5 + 2h_6 + 4h_7 + 2h_8 + 4h_9 + h_{10})$$

where w = distance between ordinates Note that h_0 and h_{10} in the figure are each zero in value

4 Determine in same units the size of one unit area (e g., 1 sq mi) by use of scale of map, divide area within lake outline by area within unit area (1 sq. mi) and quotient will be area of lake in square miles

General Considerations

a In general, the greater the number of ordinates used the greater the accuracy of results.

b. It must be understood that this method gives only approximate values and seldom will yield the accuracy of methods described on preceding pages

c. Results are better with lakes having very regular shore lines

Method by Use of Average Ordinate Rule

EQUIPMENT Map of suitable character and scale, rulers; dividers, triangle.

Procedure

1. As in Fig. 22, draw line *WX* and erect tangents *WV* and *YZ* Divide line *WY* into *any* number of *equal* parts

2. Bisect lines *WA*, *AC*, *CE*, etc , and at middle of each draw ordinates (broken lines in Fig. 22).

3. Measure lengths of all ordinates within map From sum of lengths of all ordinates, determine *average length* of these ordinates, multiply by length of line *WY* and result will be area within figure

4 Determine in same units the size of unit area (e g., 1 sq mi) by use of scale of map. Divide area within lake outline by area within unit area (1 sq. mi) and quotient will be actual area of lake in square miles.

General Considerations

a. In general the greater the number of ordinates used the greater the accuracy of results.

b. This method gives only approximate results

c. It is sometimes convenient and timesaving to determine the lengths of ordinates by means of dividers Lay off successively on a long sheet of paper the ordinate lengths in one connected straight line, and then measure total length of this composite line to get sum of lengths of ordinates

LENGTH OF SHORE LINE

Sometimes the length of a shore line may be determined directly in connection with the field survey. Often, however, it is necessary to get this information from maps and the following methods are presented for that purpose.

Map Measurer Method

A map measurer (Fig 20, *right*), sometimes called a map measure or a chartometer, is an instrument designed to measure the length of lines by means of a tracing wheel whose revolutions are transmitted to a revolving

hand operating over a graduated dial. Graduations on the dial are so constructed that they represent units of distance traversed by the tracing wheel, usually inches and fractions of inches, or centimeters and fractions of centimeters. Map measurers are made in various forms and with various scales. In some models the tracing wheel is also graduated and an index pointer mounted on the frame and superimposed over the exposed part of the wheel facilitates the reading of the wheel position.

EQUIPMENT. Map measurer; map of suitable character and scale.

CORRECTIONS AND ADJUSTMENTS. Test map measurer for accuracy as follows. Choose meter stick which has been carefully checked for straightness of edge and for accuracy of graduations, lay meter stick flat on smooth table surface, set hand of map measurer at starting point of scale. Choose some graduation mark at one end of meter stick as starting point; set map measurer against edge of meter stick with axle of tracing wheel exactly at starting graduation. Holding map measurer steadily against edge of meter stick and tracing wheel constantly against table surface, trace length of meter stick, stopping instrument at some graduation near opposite end. See that axle of wheel coincides with end graduation, compare distance covered on meter stick with distance indicated on dial of instrument. Make at least three trials. If meter stick and its graduations are correct within expected limitations and if map measurer fails to agree with meter stick, it will be necessary to prepare a correction table for the instrument.

Procedure

1. Mark with pencil dot some starting point on shore line of map, set map measurer hand at zero point on dial, carefully set axle of tracing wheel directly over starting dot on shore line, or if tracing wheel is graduated, set zero mark of wheel over starting dot.

2. With handle of map measurer held vertically, run tracing wheel along shore line in direction which causes dial hand to move continuously clockwise. Continue tracing until wheel stops exactly at desired destination. Dial will then register distance over which tracing wheel passed. If necessary, apply corrections to results.

3. In similar way and with same precautions, run map measurer over unit on scale of map (1 mi.), if necessary, apply corrections to results, divide length of shore line on map by length of unit (1 mi.) on scale of map and quotient will be actual length of shore line in miles.

General Considerations

a. Accuracy of results depends largely on the care exercised in using the instrument. Since at first the personal error may be large, preliminary practice with the instrument is highly desirable.

b. At least three tracings should be made in order to check results.

c In using the instrument, keep a moderate pressure on the handle to insure that the tracing wheel maintains close and continuous contact with the surface of the map.

Pins and Thread Method

If map measurers are not available and if the map used is not too small, good results may be secured by a simple method in which a thread is made to lie on the shore line and conform closely to its configuration. The length of such a thread is converted into units of shore-line length by means of the scale on which the map is drawn.

EQUIPMENT Map of suitable size and character, preferably larger than $8\frac{1}{2} \times 11$ in, generous supply of No 5 standard-length insect pins, or their equivalent, linen, silk, or other kind of *inelastic* thread of convenient size, beaverboard or some soft smooth board against which the map can be fastened securely and into which pins can be set with ease, meter stick or rule of convenient type

Procedure

1. Set pins vertically along edge of shore line in form of palisade, number of pins per unit of length depending upon irregularity of shore line; along convex (toward the water) portions of shore line, set pins on outer edge of line, along concave (toward the water) portions of shore line, set pins on inner edge of line, set pins thick enough to insure that thread drawn against their bases will follow contour of shore line closely

2 Mark with pen or pencil dot some point on shore line as starting point; tie knot in one end of thread, thrust pin through knot, and set on starting point, lay thread along outside of bases of concave rows of pins and against inside of bases on convex rows, draw thread to remove all slack and to cause it to lie upon and coincide smoothly with shore line, when free end of thread reaches pinned end, mark former with ink or pencil mark.

3. Remove thread and measure length between its two marked points, measure length of unit (1 mi.) on scale of map, divide length of shore line on map by length of unit (1 mi) of scale on map and quotient will be actual length of shore line in miles.

General Considerations

a The accuracy attained by this method depends much upon the use of a map of adequate size, and upon personal care and patience in operating the method. When carefully employed quite satisfactory results are obtainable

b Make three trials with thread about pins to check results

Dividers Method

Under suitable conditions, shore line may be measured by stepping off small, uniform intervals of known length on the line with a pair of dividers, counting the total number of such intervals, and dividing that total by the number of similar intervals in the length of some unit of the scale on which the map is constructed

EQUIPMENT Map of suitable size and character, preferably larger than $8\frac{1}{2} \times 11$ in., pair of good dividers.

Procedure

1 Mark starting point on shore line with pen or pencil dot; set divider points at some convenient interval and lock in that position, making interval as small as practicability will permit

2. With one point of dividers on starting dot, step off a continuous series of uniform divider intervals around the entire shore line, mark all extremities of divider intervals with mark or puncture, count total number of such intervals required to cover entire shore line

3. With dividers set for same interval, determine number of intervals necessary to cover one unit (e g , mile, meter) on scale on which map is built, divide this number of intervals into total number of intervals for entire shore line and result will be shore-line length in terms of unit provided in scale of map

The accuracy of this method depends upon the same conditions mentioned in the previous method With proper care and a large map satisfactory results are obtainable Obviously, the smaller the divider interval and the larger the map, the greater the accuracy

SHORE DEVELOPMENT

Degree of regularity or irregularity of shore line is expressible in the form of an *index figure* The term *shore development* refers to the ratio of the actual length of shore line of a lake to the length of the circumference of a circle the area of which is equal to that of the lake If a lake had a shore line in the form of a circle—a very rare circumstance—the shore development would be 1 As the value of this ratio increases beyond 1, increasing irregularity is indicated This method of indicating form of shore line is very convenient and quite generally used The following simplified formula may be employed

$$\textit{Shore development} = \frac{s}{2\sqrt{a\pi}}$$

in which s is length of shore line, a is area of lake

In the past, occasional use has been made of another ratio known as *absolute shore development* which is computed by dividing the length of the shore line by the square root of the area

HYPSOGRAPHIC CURVE

A hypsographic curve for subsurface horizontal areas is constructed by plotting depth along the vertical axis (ordinate) and area along the horizontal axis (abscissa). Such a curve not only represents certain elements in the form of the lake basin but it also provides a means whereby areas at any depth level may be determined.

Procedure

1. On well-constructed hydrographic map, measure area circumscribed by each submerged contour For best results such contours usually should be drawn at depth intervals not exceeding 2 meters By means of scale on map convert measured areas into actual areas in lake

2 Examine cross-section paper to be used, determine appropriate and convenient scale for values to be plotted along each axis Place zero point for both sets of values at upper left intersection of first ordinate and first abscissa Plot depth along vertical axis and areas along horizontal.

3. If actual areas within contours are plotted, the curve may be called a *direct hypsographic curve* If, on the other hand, the areas within submerged contours are expressed in terms of per cent of surface area of lake, then the curve is referred to as a *percentage hypsographic curve*

PROFILES

A profile is a pictorial representation of basin configuration along a selected line. This line is usually straight, but profiles may be drawn along one of any shape if occasion demands. A profile also provides one of the best methods of portraying basin slope along a selected transect. Profiles may be constructed in several ways one of which is as follows

1 On a hydrographic map of suitable scale and character, draw a selected line of profile Then on another sheet of paper, preferably a sheet of cross-section paper, draw a line the same length as the profile line on the map, this is to be the base of the profile

2 Choose a suitable vertical scale Lay paper bearing the base of the profile upon the hydrographic map in such a way that selected line of profile and the base-of-profile line are edge to edge with the ends coinciding.

3 Using the chosen vertical scale, mark, at as frequent intervals as the map provides, the depths perpendicular to profile base line Connect all points so located by a continuous line, this line will be the profile

General Considerations

a In certain instances some vertical exaggeration may be necessary, particularly when the lake is shallow or when the profile is drawn on a very small scale The amount of such exaggeration will depend upon circumstances and the purposes of the profile but should not be more than strict necessity demands. Even then, care must be taken that exaggeration does not give false impressions In all instances the amount of exaggeration must be clearly stated.

b It must be remembered that a profile gives information which is applicable only at the particular transect involved Additional information must be secured by making other profiles along transects drawn elsewhere on the map.

c. The position of a profile must always be definitely indicated.

VOLUME

The volume of a lake can be determined by computing the volume of each horizontal stratum as limited by the several submerged contours on the hydrographic map and taking the sum of the volumes of all such strata Several formulas for computing volumes of these strata are available but it appears that many of them give essentially the same results, the differences being well within the other errors of the method.

Procedure

1. Determine surface area of lake (see p. 79), also determine area circumscribed by each submerged contour.

2 Compute volume of first (uppermost) horizontal stratum bounded by the surface and the plane circumscribed by first submerged contour, using the formula

$$Volume = \frac{h}{3}(a_1 + a_2 + \sqrt{a_1 a_2})$$

in which h is vertical depth of each stratum, a_1 is area of upper surface and a_2 is area of lower surface of stratum whose volume is to be determined.

3 Compute in like fashion the volumes of succeeding strata. The sum of volumes of the several strata is total volume of lake.

VOLUME DEVELOPMENT

In order to express the form of the water mass or the form of the basin, an index figure known as *volume development* is used. This expression represents the ratio of the total volume of a lake to the volume of a cone whose area of base is equal to the surface area of the lake and whose

height is equal to the maximum depth of the lake It may also be computed by the use of the simplified formula

$$Volume\ development = 3\ \frac{(md)}{mxd}$$

in which *md* is the mean depth of lake, and *mxd* is maximum depth of lake

When the value of volume development approaches unity, the lake basin is close to the form of a cone whose height is the maximum depth of the lake and whose base is equal to the surface area of lake, when the lake basin walls are essentially convex toward the water the index figure may be less than unity, when the basin walls are concave toward the water the index figure is likely to be greater than unity

VOLUME CURVES

Volume curves not only exhibit certain structural relations of the lake basin but also make it possible to derive information from them by interpolation. A convenient volume curve is one constructed by plotting depths along the ordinate and the superimposed volume above each submerged contour along the abscissa.

Procedure

1. From data already obtained in determining total volume of lake, compute that volume of lake superimposed above level of each submerged contour.

2 Examine cross-section paper to be used and determine an appropriate and convenient scale for plotting along each axis Place zero point for both sets of values at upper left corner Plot depth along vertical axis and superimposed volume along horizontal.

3. If actual values of superimposed volume are plotted, then the curve is called a *direct volume curve*, if the data on superimposed volumes are computed in terms of per cent of total lake volume and then plotted, the curve is called a *percentage volume curve*.

SLOPE OF BASIN

The slope of the basin of a lake is usually expressed in per cent, although formulas are available for expressing the same result in degrees In limnological practice a need for one or both of two approaches to bottom slope measurement may arise, namely, the determination of the slope between two submerged contours or isobaths, and the determination of the mean slope for an entire lake having several submerged contours

Slope between two adjacent contours may be calculated by means of the formula

$$S = \frac{C_1 + C_2}{2}\ \frac{l}{A}$$

in which S is the slope in per cent between the two contours, C_1 and C_2 are the lengths of the two contours involved, I is the vertical distance or interval between the two contours, and A is the area of the bottom included between the two contours.

The mean slope of the entire lake may be calculated from the formula

$$S = \left(\frac{\frac{1}{2} C_0 + C_1 + C_2 + C_3 + \text{------} + C_{n-1} + \frac{1}{2} C_n}{n} \right) \frac{D}{A}$$

in which S is mean slope in per cent; C_0, C_1, C_2, C_3, are the lengths of the contours, n is the number of contours, D is maximum depth of the lake, and A is surface area of the lake.

Streams

LENGTH

The length of streams may be determined in two principal ways (a) direct measurements in the field, and (b) measurements from maps of suitable character, scale, and accuracy Direct measurements may be available from the original field survey. In smaller streams results of reasonable accuracy may be secured by rapid chaining along the bank or in the channel, or approximate results by pacing and by pedometer Measurements from maps may be done satisfactorily by means of any one of the methods described for the measurement of lake shore lines (p. 90). The most convenient method is that of the map measurer

WIDTH

Stream widths are usually measured in the field The problem of measuring stream widths directly presents difficulties owing to the fact that great variations arise from changes of water level. Often the method and number of direct measurements must be matters of judgment and practicability as determined by local circumstances and the needs of the work For limnological purposes it is not sufficient merely to make measurements at convenient and easily workable places Some system of measurement must be employed which will include all parts of the stream from the narrowest to the widest and which will show the essential variation if such measurements are to have any dependable significance For results of a statistical analysis of stream-width measurements consult Embody, Goodrum and Edmond (1938), see p 98 In field work, stream-width measurements may be based upon (a) a selected water level, (b) general channel width, or (c) high-water level. In limnological work, the one first mentioned is usually preferable The common need is to determine a *mean width* accurate within certain desirable limits

Measurement of stream width on ordinary maps of small scale is usu-

ally out of the question. Dependable measurements can be made only on such maps as show particular sections of a stream on a very large scale and which have been drawn from careful and detailed field surveys

OTHER MORPHOMETRIC CONSIDERATIONS

Means of making other morphological measurements of streams are easily derivable from methods previously described for work on lakes To have any value at all, areas, shore lines, volumes, longitudinal and transverse profiles, and similar features must be based upon very careful, detailed surveys and the resulting hydrographic maps drawn on a very large scale. Shore development is computed on the same basis as described for lakes, (p 93)

Selected References

(For Chapter 6)

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Part II

Physical Methods

TEMPERATURE

Since the direct and indirect relations of water temperature to limnological phenomena are both numerous and fundamental, methods of measuring heat content at different depth levels are of prime importance. From the large number of devices now available, those described here are selected because of their general usefulness and dependability.

Surface Temperatures

Measurement of surface-water temperatures is usually a simple matter. Any good grade, simple type of thermometer properly used will suffice. A common chemical thermometer graduated to 0.2 degree C. is a convenient instrument for many kinds of field work. Such an instrument should be provided with a metal case equipped with a clip, chain, or other means of attachment to clothing of the operator to avoid loss in the field.

A good grade maximum-minimum thermometer (p. 118) is not only useful for occasional recording of surface-water temperatures but also is particularly adapted to the measurement of daily maximum and minimum temperatures over a period of time. For routine daily maximum-minimum temperatures, such an instrument should be mounted in a vertical position on a dock post, retaining wall, or other stationary object situated in the desired location. It must also be fixed far enough below the surface of the water so that it will always be submerged irrespective of irregularities of wave action, so disposed that it can be read conveniently, and so protected that it will not suffer damage from storms, floating debris, boats, and accidents in general. However, it often happens that daily maximum-minimum temperatures of the open surface water remote from shore are required and in such an instance it will usually be necessary to install the thermometer on a buoy anchored at the selected station. A useful buoy is illustrated in Fig. 23. It consists of a cylindrical piece of log about 15–20 cm. in diameter, about 1 m. long, and tapered at the lower end. To one side of this block is spiked a wooden staff at the free end of which a red, or a red-and-white, flag about 30 cm. square is attached. On the opposite side of the log and projecting downward is spiked a strong staff, about 1–1.7 m. long, at the free end of which is firmly attached a weight of suitable size and form. This weight serves as a counterpoise and must be adjusted to hold each individual buoy in the proper position and floating at the desired level. Large blocks of cork may be nailed to the sides of the log

to prevent waterlogging. Several coats of waterproof paint applied to the log will accomplish the same purpose Through a large smooth hole in the lower end of the log is tied one end of a 2-cm (¾-in) manila hemp anchor rope The length of this anchor rope should be at least 1 5 times the total depth of the water in which the buoy is to be installed The anchor may be a piece of scrap iron, concrete block, stone harnessed with strong wire, or any other similar object whose weight will insure against dragging and whose form is suitable for convenient handling On the side of the log there is stapled a piece of large-size, stiff, electrician's copper wire bent, as shown in Fig 23, into an inverted U, at the free end of which a maximum-minimum thermometer is securely attached in vertical position. The thermometer is thus held free from contact with any part of the buoy. The life of an anchor rope will be prolonged if it is soaked in hot paraffin or otherwise waterproofed A thin coat of petroleum jelly will protect the metal parts of the thermometer if they are not rustproof. Tie-on surfaces for both ends of the anchor rope must be broad and smooth, otherwise the almost incessant motion of the buoy will cause wear and, ultimately, its casting loose A buoy of this sort is much more likely to remain in place during violent storms than those having larger surfaces on which water movement may act. A thermometer so installed may be read whenever occasion demands, but for general purposes once every twelve hours, as for example, 7 00 A M and 7 00 P M., will suffice The index in each arm of the thermometer must be reset with a magnet after each reading If it is necessary to lift the instrument out of water for purposes of reading, return it to water quickly to avoid the possible effects of atmospheric temperatures. *Caution* In selecting a maximum-minimum thermometer for installation on a buoy, care must be taken to determine in advance whether the instrument so chosen is subject to error caused by the motion of the buoy shifting the position of the indices. Such liability of indices in maximum-

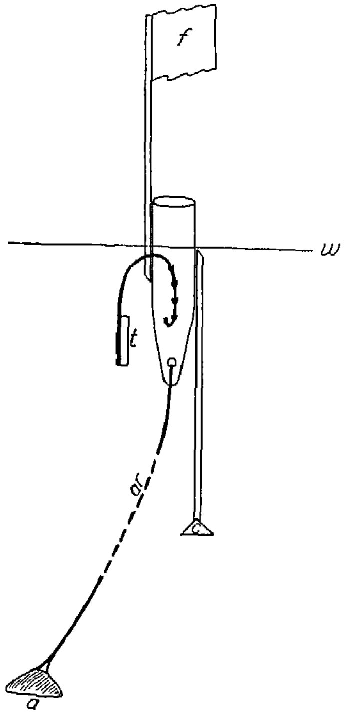


FIG 23 Structural features of a buoy designed for the support of a recording thermometer. (*a*) Anchor (*ar*) Anchor rope (*c*) Weight (*f*) Flag (*t*) Thermometer. (*w*) Surface of water Other features described in text.

minimum thermometers in general to shift position in response to vertical motion is a possible source of error which must be guarded against However, it is usually possible to select an instrument which can be shown to resist this shifting of the indices Such an instrument fastened to a buoy can be checked for index shifting by comparing its readings with those of a similar thermometer mounted on an adjacent nonmovable object in the same depth of water.

In ordinary measurements of surface temperature in quiet water, it is only necessary to submerge the thermometer in an inclined position and make the reading, after an adjustment interval, without removing the instrument from the water If the water is rough, the temperature can be determined by dipping up a container full of surface water and immersing the thermometer in it

Thermometers used exclusively in surface water need to be corrected for temperature only since for this purpose the hydrostatic pressure is negligible.

Subsurface Temperatures

Measurements of temperature at various depths below the water surface require instruments designed for that purpose. Since temperatures often differ greatly with depth and since most of the positions at which temperature is to be measured are remote from the observer and hence invisible, the construction of these devices must be thoroughly understood and their possible errors known. Such instruments when lowered into water meet rapidly increasing hydrostatic pressure, consequently, they may require correction for pressure as well as for temperature, depending upon the nature of their construction.

REVERSING THERMOMETERS

Of the instruments used for measurement of subsurface temperatures, reversing thermometers are commonly rated as among the best. They are also referred to under other names, such as "deep-sea thermometers," "turnover thermometers," and the names of their makers Various types are made, all based essentially upon the same principle, namely, the 180° reversal of the thermometer, after the required period of adjustment, in which a column of mercury, whose length is a measure of the temperature at the selected level, is detached and delivered into the opposite end of the capillary tube No subsequent additions to or subtractions from the detached mercury column can occur until the instrument is brought to the surface and turned back into the original position

A widely used, high-class reversing thermometer is one manufactured by Negretti and Zambra, London, England, and the following description is based upon that type (Fig. 24). This instrument usually consists of

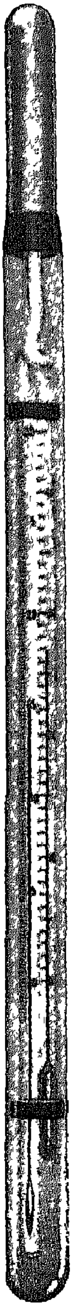
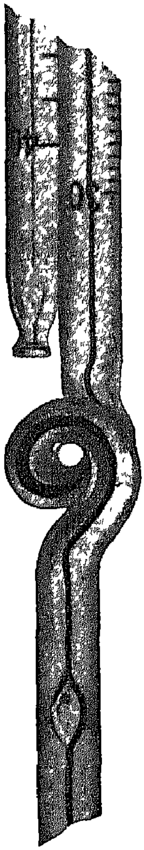



FIG 24 Reversing thermometer. (*Left*) Complete thermometer in *reversed* position (*Right*) Portion of main thermometer, in *nonreversed* position, showing details of construction in region of coil (Courtesy, Negretti and Zambra, London, England)

two thermometers, a main and an auxiliary thermometer, both in one sealed glass sheath. The main thermometer is the device which makes the temperature measurement at the selected level, the auxiliary thermometer is for purposes of making certain corrections to be described later

The main thermometer has a long, narrow mercury reservoir at one end which is surrounded on the outside, i e , the space between the mercury reservoir wall and the surrounding, outer glass sheath, by a layer of mercury, sealed in place, to facilitate the response to temperatures The stem leading from the main reservoir is coiled Above this coil the stem is straight and on it are graduations numbered in the reverse direction. A short distance above the mercury reservoir there is a special form of constriction in the bore of the capillary tube Then follows a short, straight section of uniform bore, leading to the coil in which the bore becomes considerably enlarged After passing through the coil, the bore becomes uniform, extending to the opposite end of the thermometer where it expands into a small fusiform reservoir. When the thermometer is in a vertical position with the large reservoir down, the mercury column is continuous from the reservoir to its termination in the capillary tube above. As it descends into the water in this position it acts as an ordinary thermometer, the upper end of the mercury column shifting in position in response to the temperature of the various strata through which it passes When the selected depth is reached, the instrument is allowed to remain at that position for an adjustment period of at least 1 or 2 min , or longer in case of

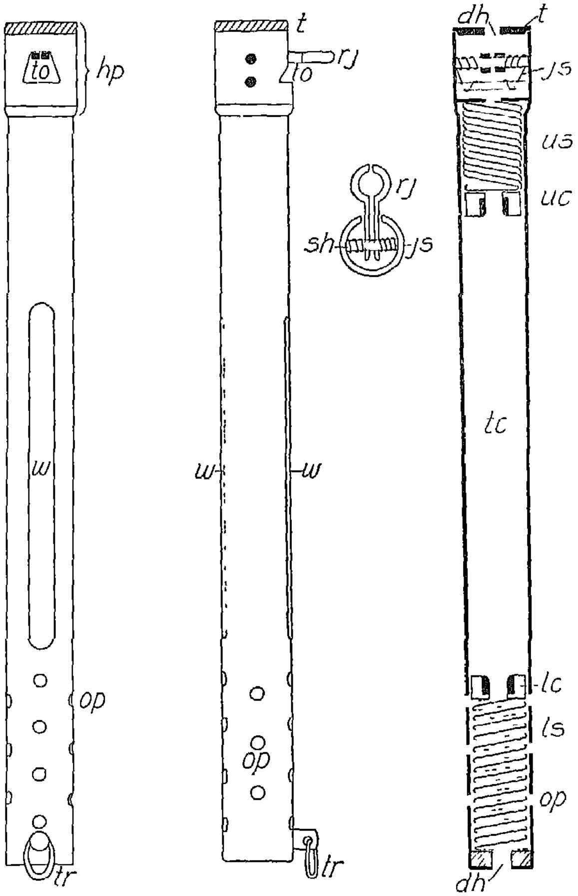


FIG 25 Metal case for reversing thermometer Figure to left and figure in middle represent external views of whole case Figure to right is a median sectional view showing details of internal construction Small figure shows essential details of releasing mechanism (*dh*) Drain hole (*hp*) Removable headpiece (*js*) Spring operating release jaws (*lc*) Sliding, circular, rubber-lined collar at lower end of thermometer chamber for support of main-reservoir end of thermometer (*ls*) Lower coiled spring on which thermometer is supported. (*op*) Lateral openings providing free circulation of water through interior of that part of case which contains principal mercury reservoir (*rj*) Release jaws (*sh*) Rotating shaft on which release jaws operate (*t*) Removable top piece (*tc*) Thermometer chamber (*to*) Triangular opening in wall of case through which release jaws operate, when at top position of opening, jaws are closed, when at bottom of triangular opening, jaws are spread apart (*tr*) Tie-on ring (*uc*) Sliding, circular, rubber-lined collar at upper end of thermometer chamber which supports upper end of thermometer. (*us*) Upper coiled spring on which upper end of thermometer is supported (*w*) Elongated window through which thermometer is read

doubt, then a metal messenger, sent down the rope, releases the tripping device and the thermometer turns over. The effect of the sudden reversal is to separate the mercury column at the constriction point so that it runs into the opposite end of the instrument, filling the fusiform reservoir and a certain portion of the capillary tube The length of this detached mercury column is a measure of the temperature at the selected level The instrument is now brought to the surface and read in the reversed position.

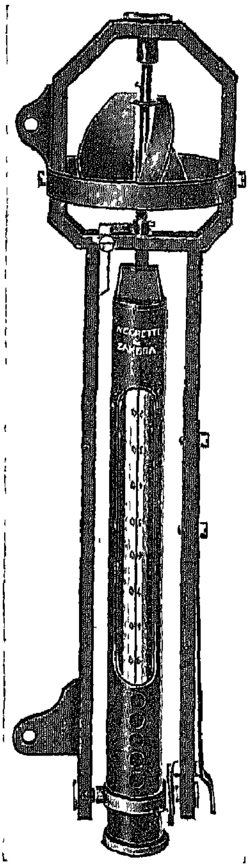


FIG. 26 A frame for reversing thermometers in which release mechanism is operated by a propeller (Courtesy, Negretti and Zambra)

In order to function properly, a reversing thermometer must be housed in a special metal case the mechanical construction of which is such that it can be reversed at the selected depth level (Fig 25) either by a messenger sent down on the line or by a propeller which rotates when it is pulled a short distance through the water (Fig 26)

CORRECTIONS Reversing thermometers are subject to two classes of errors, structural and functional

By structural errors are meant those which arise from failure of the instrument to be true to standard at any of the temperatures and pressures involved in ordinary operations Such corrections should be secured by submitting the instrument to some well-known standardizing agency, such as the U S. Bureau of Standards It is usually possible to secure, at a modest increase in cost, instruments which have certificates of correction already prepared Usually it is not necessary to consider a correction which is less than one-tenth of the smallest division shown on the thermometer graduations, which on Negretti and Zambra thermometers is one-fifth of a degree C Instruments made by the company just mentioned are usually certified as satisfactory under pressures up to 3 tons per sq in

By functional errors are meant those which occur in the changes in volume of the detached mercury column when it passes through waters of different temperatures on its return journey to the surface, changes which are often so slight as to be negligible for some limnological purposes In fact certain kinds of reversing thermometers are made without any provision for corrections of this sort However, it is

sometimes desirable to have subsurface temperatures determined as accurately as possible, and to meet this need the auxiliary thermometer, previously mentioned, is included within the instrument It is a smaller straight thermometer fastened against, and parallel to, the main thermometer, with its graduations in readable position when the main thermometer is reversed. This auxiliary thermometer shows the temperature of the detached mercury at the time of the reading The correction is calculated from the formula·

$$c = tva$$

in which

- *c* is the correction sought,
- *t* is the *difference* in temperature between the reading on the main thermometer and that of the auxiliary thermometer,
- *a* is the coefficient of apparent cubical expansion of mercury in the glass of which the thermometer is constructed (usually about $\frac{1}{6000}$ per degree Centigrade, value sometimes marked on main thermometer), and
- *v* is the reading of the main thermometer *plus* the volume which would have been detached if the reversal had been made at 0° C (this "volume at 0°" value is engraved on the main thermometer).

For example if
main thermometer reads 18°,
auxiliary thermometer reads 24°,
volume at 0° is 79, and
coefficient of expansion of mercury in the glass is $\frac{1}{6000}$, then

$$(24-18) \times (79+18) \times \frac{1}{6000} = 6 \times 97 \times \frac{1}{6000}$$
$$= 0.09°$$

Corrected temperature reading is 18 – 0.09 = 17 91°

The correction, when determined, must be either subtracted or added to the reading made on the main thermometer at the surface. Under ordinary circumstances as they prevail in lakes during the summer, the water becomes cooler with increasing depth; therefore, when the thermometer is reversed at some distance under water, the main and the auxiliary thermometers show, at the reversal level, the same reading if the proper adjustment interval has been provided, but in the passage to the surface through increasingly warmer water the detached mercury column expands, therefore, the correction value must be *subtracted*. In midwinter under the ice cover, the water temperature often becomes warmer with increasing depth (to 4° C.) in the deeper lakes; therefore, the correction

value must be *added.* These temperature relations with increasing depth are known to the observer since ordinarily vertical temperature series are made progressively from the surface downward. Special circumstances in which even in summer colder water may exist *above* warmer water because of differences in density should be watched for if only deep water temperatures are taken, in a vertical series such relations are obvious to the observer when the series progresses from the surface downward

DEFECTS AND ADJUSTMENTS A defect which seems to be common in all types of reversing thermometers is their liability to develop errors of performance suddenly when a particle of residual gas, displaced from the small reservoir at the top of the thermometer, gets into the mercury column, causing breakage of the latter at the wrong place when reversed. As explained by the makers, great precaution is taken in the manufacture of these thermometers to exclude all gas from the tube. However, a minute quantity of gas is likely to be left in the system in the sealing-off operation or such gas becomes apparent after the instrument has aged This gas particle is exceedingly minute and not visible in the mercury If this gas particle remains in the reservoir at the top of the thermometer it not only gives no difficulty but actually is something of an advantage since it tends to prevent the mercury from "locking" in the top of the instrument If, however, the gas particle gets into the mercury it will cause breakage of the mercury column at that point instead of at the normal breaking point and "locking" of the mercury in the top reservoir after reversal becomes a more frequent occurrence. When the error in breakage is large it can usually be detected at once but if it involves only a fraction of a degree it may be overlooked For this reason some workers insist that reversing thermometers should be used in pairs mounted together in the same reversing mechanism (Fig 27). This defect seems to arise usually (a) as a result of improper storage of the instrument when not in use, (b) in transportation, and (c) in instruments which are several years old To clear this gas particle from the mercury column, some makers advise cooling the thermometer in ice, then heating it up, cooling again, repeating this process several times This heating-up process must be done with great caution

When the mercury column "locks" in the upper reservoir it can sometimes be dislodged by swinging the thermometer centrifugally If this treatment fails to dislodge the column then the makers (Negretti and Zambra) state that it is best to heat the upper reservoir in warm water until the thread of mercury in the capillary tube connecting with the upper reservoir is of sufficient length to assist the down pull when centrifugal force is applied by swinging After the column is restored, it is very important that the thermometer be cooled in ice and heated several times since the fact that the mercury locked suggests that a particle of gas

has been displaced from the upper reservoir and is somewhere in the capillary tube.

REVERSING CASES. Mechanisms for the protection and for the reversing of such thermometers are made in many different forms. Two types are common, one of which is operated by a messenger (Fig. 25), the other by a propeller which spins when the whole mechanism is drawn vertically for a short distance (Fig 26) after the adjustment period In either type the thermometer is allowed to fall over and come to rest after a change of position of 180°

REVERSING FRAMES. Detection of abnormal performance in a reversing thermometer can be accomplished in several ways, a quick and convenient one being the simultaneous reversal of two or more thermometers at the same depth level and in the same reversing frame. The frame described here was designed by the writer Since the operation of reversing thermometers, when used singly, requires that each be housed in a special metal reversing case (Fig. 26), this frame was designed to receive such thermometers without removing them from their cases. A central bar flanked by two rods constitutes the supporting element. At each end is a plate (Fig 27B, D). Each plate has two cups, the size and form of each adapted to receive the ends of the thermometer cases. On one side, the cups are deeper in order to provide for possible differences in the length of the thermometer cases. Other details are shown in Fig. 27. The length of this frame is such as to hold two thermometer cases snugly and safely in place.

To make ready for use, unscrew wing nuts *wn;* pull out locking staple *ls,* untie line *to,* and remove lower plate Insert upper ends of two thermometer cases containing two reversing thermometers into cups c_3 and c_4; replace lower plate, making cups c_1 and c_2 engage tie-on ends (main mercury reservoir ends) of thermometer cases, if necessary put soft packing material in bottoms of cups to immobilize thermometer cases completely, screw down wing nuts *wn* and insert lock staple *ls;* test thermometer cases again to make certain that they are safely and firmly installed in frame; then set up frame in position shown in Fig 27A The instrument is now ready to be lowered into the water When it reaches the desired depth level and the proper adjustment interval is concluded, a metal messenger, descending on the line, strikes the top of the trip mechanism, releases the ring *rr.* The frame falls over, reversing the thermometers When brought to the surface the two thermometers should register exactly the same temperature; if they do not, at least one of the two thermometers is behaving abnormally. Remove one thermometer from the frame, introduce a third one in its place and repeat the procedure. By this means the faulty instrument may be detected. If a third reversing thermometer is not available, the two used in the reversing frame

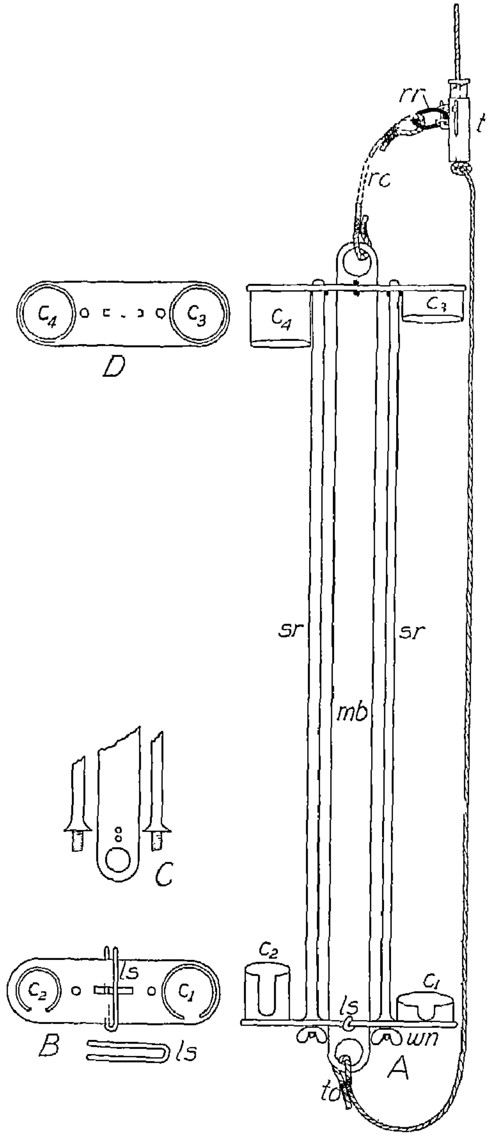


FIG 27 Frame for reversing two thermometers simultaneously at same depth level. (A) Front view of complete frame. (B) Lower, removable plate showing locking staple in position (C) Detail of lower end of frame with lower plate removed (D) Upper, nonremovable plate (c_1 and c_2) Cups for holding lower ends of reversing thermometer cases, side slots for reception of tie-on posts and rings on thermometer frames (c_3 and c_4) Cups for holding upper ends of reversing thermometer cases (*ls*) Locking staple (*mb*) Middle bar (*rc*) Release cord (*rr*) Release ring (*sr*) Side rod (*t*) Trip mechanism (*to*) Tie-on at lower end of frame. (*wn*) Wing nut

may be tested in the laboratory against another kind of temperature-recording instrument.

Since the operation of two thermometers in this frame is as simple as that of a single one, the regular practice of using a pair simultaneously should be considered seriously by careful workers. Very old thermometers, those which have been long in storage, and those which have been shipped by public transportation must be tested for normal performance before making serious use of them. New instruments must not be accepted blindly on faith. Not all kinds of reversing thermometers are equally good and dependable and those made by manufacturers newly in that kind of production should be tested very carefully.

By means of a few simple structural changes this reversing frame can be enlarged to contain three or four reversing thermometers.

General Considerations

a. When not in use, reversing thermometers should always be stored in a vertical position with the large mercury reservoir down. This procedure minimizes the danger (1) of dislocating a gas bubble from the upper reservoir with resulting break of the mercury column at the wrong place and (2) of the possible locking of the mercury column in the upper reservoir.

b. When not in actual use, these instruments should be kept in a long field case with a strap handle at the upper end. Such a case affords general protection and also a convenient means of hanging the instrument in the correct position.

c. Reversing thermometers may be broken if reversed against rocks on the bottom especially in shallow waters. If the nature of the bottom is not known, a sounding test should be made before a thermometer is reversed at the lowermost position.

d. Every new reversing thermometer should be tested before being put into active use. This test can best be done on a lake where various pressures and temperatures are available in a vertical series. The test can be made by mounting the new instrument in a twin reversing frame (Fig. 27) with another reversing thermometer of known dependability and reversing both simultaneously at various depth levels; or a similar test can be made with some other type of temperature-measuring device, such as a thermophone or an electric-resistance thermometer, by comparing simultaneous readings at the same depth levels.

e. Since in the shallower depths messengers strike tripping devices with considerable force, the battering effect of these impacts is minimized by covering the prongs of the trip on the instrument case with pieces of ordinary rubber tubing of the proper size. It is also desirable that a knot be tied in the graduated rope about midway between the two ends of the

thermometer case in order to prevent messengers from striking the tie-on link.

f. A carefully tested reversing thermometer of the highest class construction which has been completely certified by an official standardizing bureau serves as an excellent standard against which to compare other instruments for measuring temperatures at various depths

g Reversing thermometers, more or less similar in design to those of Negretti and Zambra but lacking the outer, heavy, protecting glass sheath, are obtainable Such instruments cannot be used at great depths without risk of crushing and tests for the effects of hydrostatic pressure are imperative

THERMOGRAPHS

Many of the various forms of thermograph are adaptable to limnological work Types originally designed for continuous records of temperatures in air and soil are easily turned to the needs for similar records in water Thermographs have been designed or adapted for the taking of such records in water with installations on hulls of boats or at stations located near or on shore Recently an instrument known as a bathythermograph (Spilhaus, 1937, 1940) has been devised which appears to have promise of important value in both oceanographic and limnological work The essential feature of the instrument is the provision whereby a very detailed record of the vertical distribution of temperatures in water is secured by pen tracing against a smoked-glass as the instrument is lowered and raised in the water

THERMOPHONE

One of the most useful instruments for the measurement of subsurface temperatures is the thermophone designed originally by Warren and Whipple (1895) However, in spite of its obvious merits it is not as extensively used in limnological work as it deserves, possibly in part because of the initial cost.

The thermophone is essentially an electric thermometer which acts upon the principle that the resistance of a conductor to the passage of an electric current changes with the temperature, also that the rate of change in resistance due to temperature differs in different metals Structurally, the instrument consists of three main portions, (a) an instrument box containing batteries, Wheatstone bridge, galvanometer, and accessories, (b) a 3-wire cable of a length demanded by maximum depths of the waters to be investigated, and (c) the helix-shaped terminal at the free end of the cable which contains the sensitive coils

The terminal (Fig. 28) is a slender brass tube about 5 ft long which is wound into a coil about 6 5 cm in diameter. This tube contains two

resistance coils of two different metals which differ from each other markedly in the rate of electric conduction, as for example, copper and German silver These contrasting coils are united at one end and their other ends are each connected to a wire extending into the cable. A third wire is attached to the junction of the two coils and it also extends into the cable. The brass tube containing the coils is filled with oil and hermetically sealed. The enlargement of the brass housing tube contains the connections with the cable wires

The 3-wire cable is flexible, graduated according to some convenient scale, and usually carried on a revolving reel or drum. At the upper end, the 3 cable wires extend independently from the end of the cable and each terminates in a brass contact number to indicate which binding post on the instrument box is to receive it The temperatures of the wires in the cable do not affect the temperature reading made on the instrument since two of them are of low resistance and are on opposite sides of the Wheatstone bridge, thus neutralizing each other The third cable wire connects the junction of the two coils in the terminal with the galvanometer and is not involved in the equation.

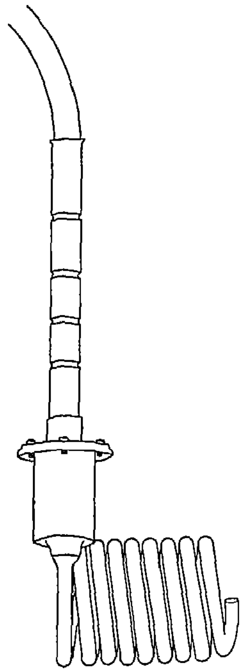


FIG 28 Helix-shaped terminal of thermophone.

The instrument box contains 3 dry-cell batteries in the battery chamber (Fig 29, *bc*), the galvanometer *g*, the combined Wheatstone bridge and switch *s-w* with dial and movable hand; and 3 binding posts for the attachment of the cable. Fig 30 is a wiring diagram for the type described here. The coils c_1 and c_2 in the terminal are connected through the cable by individual wires to the two ends of the circular slide wire *xz* (Wheatstone bridge). The two ends of this slide wire are connected in circuit at binding posts *1* and *2* with a battery *b*. The galvanometer *g* is inserted between the upper end of the third cable wire and the movable contact *y*. The galvanometer will indicate no current passing through the No. 3 wire when $\frac{c_1}{c_2} = \frac{xy}{yz}$ Since the resistances of c_1 and c_2 change unequally with different temperatures, there will be a different value for $\frac{c_1}{c_2}$ for each new temperature This value, measured by $\frac{xy}{yz}$ and expressed in units of temperature, is determined by the position of the movable contact *y* on the slide wire *xz*. In the type being described, the slide wire is

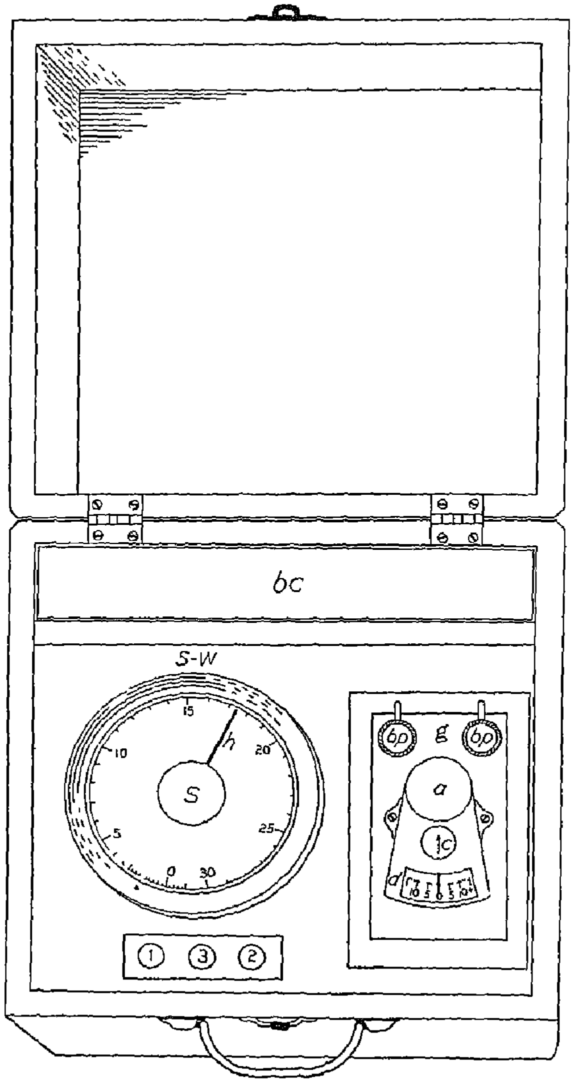


FIG. 29 Diagram showing essentials of instrument box of thermophone (*a*) Adjusting knob for galvanometer needle. (*bc*) Battery box. (*bp*) Binding posts (*c*) Sliding clamp for immobilizing or freeing galvanometer needle (*d*) Scale (*g*) Galvanometer (*h*) Movable hand (*s*) Switch. (*s-w*) Combination switch-Wheatstone bridge dial (*1*, *2*, *3*) Binding posts for lead wires in cable

wound around the edge of a circular disk above which is located a dial graduated in units of temperature. The hand *h* is superimposed directly above the sliding contact, is free to move over the dial, and both hand and sliding contact are moved by turning the knob *s* in the center of the dial

To operate a thermophone of this type, proceed as follows Place instrument case on level, firm support in position convenient for work, if in boat, select position where motion of boat will be minimized, connect upper contacts of cable with proper binding posts, *1*, *2*, and *3* (Fig. 29), tie some upper portion of cable securely to boat as measure of safety, release galvanometer needle by sliding clamp *c* into free position and carefully set needle on zero point of underlying scale *d* by means of adjusting knob *a;* lower cable terminal into water to desired depth and allow to stand for adjustment interval of 1 5 minutes; push down knob *s* in center of dial and observe performance of galvanometer needle, in its pushed-down position, turn knob in that direction (clockwise or counterclockwise) which brings galvanometer needle back to zero position, when zero is reached, dial hand *h* indicates temperature of submerged terminal

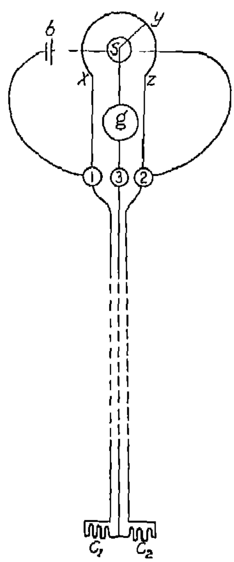


Fig 30 Wiring diagram of thermophone circuit. (*1*, *2*, *3*) Lead wires (*b*) Battery (c_1 and c_2) Coils in terminal. (*g*) Galvanometer (*s*) Switch. (*x* and *z*) Ends of lead wires attached to circular slide Wheatstone bridge (*y*) Movable contact

Advantages of Instrument The thermophone possesses advantages over most other kinds of subsurface temperature-measuring devices, as follows: (a) It is very sensitive and accurate, (b) its readings are not subject to the effects of water pressures, (c) its adjustment period is small, (d) temperatures are easily and quickly read, (e) it is not necessary to bring the terminal to the surface in order to make a record, thus saving much time, (f) at each selected position the temperature record is made within a water thickness of only about 2 5 in., (g) it may be used in any of the partly suspended bottom deposits of lakes into which the terminal may be sunk to any depth safe for the instrument; (h) it is particularly suitable for determining the successive fluctuations of water temperature at any one level, (i) with proper care it has a very long life

The only disadvantages of a thermophone, compared with a reversing thermometer are (a) weight and bulk, especially if a long cable is required, and (b) initial cost.

Testing and Correction. Since the thermophone is not affected by

pressures, it can be tested and corrected in the laboratory where water of various temperatures can be secured and against any already carefully corrected thermometer

MODIFICATION OF THERMOPHONE The cost of a thermophone may be reduced by substituting for the somewhat expensive galvanometer a current interrupter or buzzer attached to a telephone receiver. In operation, the current is turned on at a switch, the telephone is held to the ear, and the dial hand turned back and forth over the graduated dial The buzzing sound increases or decreases as the hand approaches or departs from a certain position. The silence point indicates on the dial the temperature of the terminal at the lower end of the cable This modification has also a certain advantage over the galvanometer in that there is no swinging needle to contend with under conditions of rough water

PRECISION Potentially, the thermophone is a very sensitive instrument. Limitations of precision depend upon the size of the dial and certain other features. A type built to take a dial 10 cm in diameter is usually graduated to 0.2° C, a reading of 0 1° by estimation is easy, and one to 0 05° by estimation is possible Instruments made to use larger dials possess still greater precision.

General Considerations

a A thermophone should always be tested for good condition in the laboratory before it is taken into the field

b The 3 small dry-cell batteries should be replaced from time to time, the interval of replacement depending upon extent of use of the instrument Mark date of replacement on batteries when installed In case of doubt, replace the batteries, and if remote from source of supplies, carry an extra set

c When not in use wrap both sets of cable terminals in soft, bulky cloth to protect them against damage in transportation Provide a revolving drum enclosed in a box for the cable (Fig 31)

d Establish graduations directly on the cable, either with paint, colored threads, or other permanent means

e Ordinarily there is no occasion for disassembling parts within the instrument box If trouble is serious enough to require disassembling, it will probably be preferable to send the whole thermophone to the maker or to some factory known to be competent and familiar with such instruments Avoid any changes which alter the position of the dial If, for any reason, the knob *s* in the center of the dial is removed, be sure that, on reassembling, the vertical rod connecting the knob with the switch below is restored to its proper position, if it is installed wrong end up a short will occur and the batteries will run down.

f When ready for use in a boat or elsewhere, make certain that the

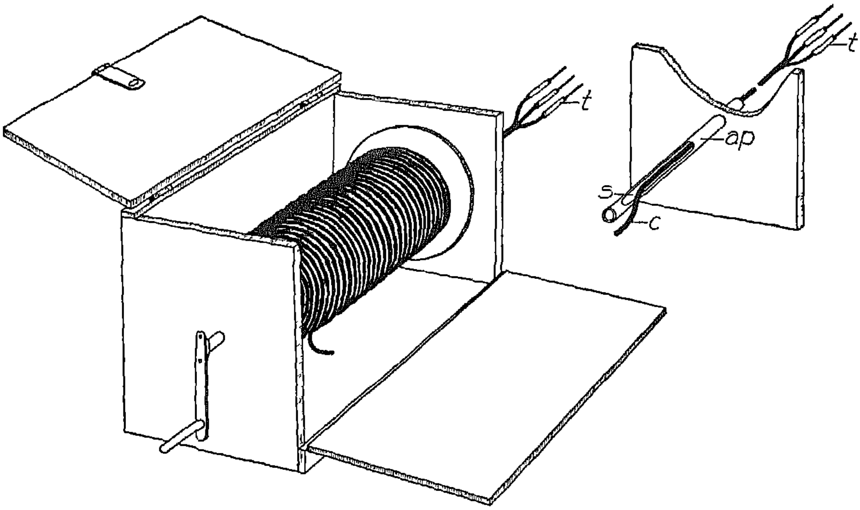


FIG 31 Drum and enclosing box suitable for storage and field use of thermophone cable (*Left*) Assembled outfit ready for use (*Right*) Portion of right end of drum box showing method of carrying terminal end (upper end) of cable through interior of axial pipe to outside of box. (*ap*) Axial pipe which supports drum. (*c*) Cable (*s*) Slit in pipe for introduction of cable (*t*) Terminals for attachment to galvanometer

The spool on which the cable is wound is composed of slats separated by narrow spaces

cable is firmly tied near its upper end to some fixed object If this precaution is neglected, there is danger of losing the cable overboard

g Every precaution must be taken to exclude water from the interior of the terminal or the cable.

ELECTRIC-RESISTANCE THERMOMETERS

Of recent years other portable types of *electric-resistance thermometers* have been developed which are adapted for the measurement of subsurface temperatures in lakes and streams These instruments resemble in many respects, both fundamental and superficial, the thermophone just described In fact, the similarities are so numerous that it is not necessary to describe the instrument in detail here. The following features may be mentioned (a) The terminal (bulb) which is lowered into the water may be of various forms, a commonly used one being a straight tube about 8 in long, the lower 3-in portion of which is the temperature-sensitive region. (b) The potentiometer is so built that the temperature scale may be as much as 17 in. long, thus making it possible to enlarge the temperature units on the scale and provide for much greater precision in subdividing the units (degrees) (c) The adjustment interval is very short

(about 30 sec.). (d) Double scales may be provided which make it possible to read results in two scale ranges (e.g., Centigrade and Fahrenheit) simultaneously. (e) Field operation is very similar to that of the thermophone. (f) The advantages and disadvantages of the instrument are essentially those listed on p. 115 for the thermophone (g) Testing and correcting, see p 115 These instruments are very accurate and possess high precision

Practically all of the items relating to the thermophone under General Considerations, pp 116–117, apply to other electric-resistance thermometer outfits.

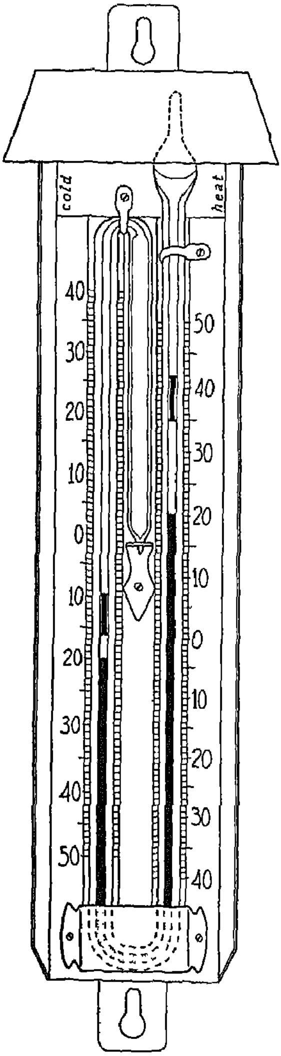


FIG. 32. Maximum-minimum thermometer (Sixes type).

MAXIMUM-MINIMUM THERMOMETER

If reversing thermometers, a thermophone, or other specially designed instruments cannot be provided, a maximum-minimum thermometer, "Sixes type," can sometimes be used to secure records of subsurface temperatures in inland waters if the limitations of the instrument are understood and certain precautions are observed.

This instrument is a self-registering type of thermometer, made by various companies and in various grades The instrument consists essentially of a U-shaped capillary tube (Fig 32) with a slender, elongated reservoir at the upper end of the left arm and a pear-shaped reservoir at the upper end of the right arm. The slender reservoir on the left and a part of the adjacent capillary tube are filled completely with a liquid (creosote). This reservoir acts as the "bulb" of the thermometer since it contracts and expands in response to decrease or increase of temperature Approximately the lower half of the U-tube is occupied by a mercury column so related to the creosote column on the left that any contraction or expansion of the latter causes a rise of one arm of the mercury column and a corresponding fall of the other. The space in the capillary tube above the right arm of the mercury column is also filled with creosote as is likewise a portion of the pear-shaped reservoir This

partly filled reservoir takes care of the increase and decrease of the liquid volume due to expansion and contraction of the creosote in the other reservoir and the U-tube In each limb of the tube there is an index above the end of the mercury column This index is a fine piece of iron wire enclosed in a glass capsule to prevent corrosion It is equipped with a device (in some types, a minute spring formed of hair or a glass filament) which introduces friction against the sides of the capillary tube and prevents the index from changing position because of its own weight. The U-tube is fastened to a metal frame in such a way that the left limb is the *cold* side and the right limb the *warm* side. Graduations occur on the frame just back of the capillary tube.

To operate the thermometer, proceed as follows set the two ends of a horseshoe magnet on the capillary tube and over the index slowly stroke downward until the index rests on the end of the mercury column, repeat this procedure on the other index, lower thermometer to the desired depth level and allow a five-minute interval for adjustment, bring instrument to the surface and read the lower end of the index on cold side (see p 121 for exception), reset with the magnet and proceed to the next selected depth

The creosote in the left-hand bulb contracts as the result of going into colder, deeper water and the mercury rises in the left hand limb pushing the index *up* the tube to the *minimum reading;* likewise, when the creosote expands as the thermometer comes back into the upper, warmer water, the index remains at the minimum position even though the mercury has retreated to some other position

CORRECTION When used for measuring subsurface temperatures, these maximum-minimum thermometers must be corrected for both temperature and pressure Fortunately, it is possible to correct simultaneously for temperature and pressure in the following way Choose a lake in midsummer whose depth is such as to provide (a) difference of about 20° C. between surface and bottom waters and (b) considerable water pressure gradient from surface to bottom Lower simultaneously to same selected depth (near surface) maximum-minimum thermometer to be tested, also already corrected instrument which serves as standard. With both standard and thermometer at same depth, make careful temperature records; lower both to another depth and repeat, continue such records at chosen intervals from surface to bottom Increasing depth not only provides increasing pressures but also provides colder and colder water thus spreading test over most of operating range of thermometer From such records a correction table can be made.

Corrections for temperature only, if needed, may be made in the laboratory in the usual way against a standard using adjusted water temperatures. If, for any reason, it is desirable to know the influence of hydro-

static pressure alone, this information can be secured by making records at various depths in a lake at the time of the spring or fall overturns when the water is homothermous. Such a series must be exactly paralleled by one taken with the standard instrument against which the corrections are made

PRECISION These instruments are usually graduated in 1° intervals With experience, readings can be estimated to 0 5°, closer estimates are uncertain.

ADVANTAGES AND DISADVANTAGES. Among the advantages of this instrument may be listed modest cost, small size, light weight, and general adaptability In subsurface work, several instruments may be attached, one at each of several selected intervals on the graduated rope, thus making records simultaneously at as many different depths as there are instruments and with a considerable saving of time The following disadvantages should be mentioned (a) It is fragile, the glass portions are unprotected, (b) it cannot be used in great depths without danger of crushing, (c) it must be brought to the surface for each record, (d) its precision is limited, and (e) it may have a defect which arises from the occasional unreliability of the indices If the device for holding the index in the tube is too weak the index will tend to slip down of its own weight in the process of handling, if it is too strong, the mercury pushes past the index thus dividing the mercury and spirit columns Every instrument must be inspected for this kind of trouble Instruments of best construction and adjustment will give satisfactory and dependable service in ordinary operations, but even they must not be subjected to rough handling or to severe vibration since indices will slip under these conditions, causing erroneous readings

General Considerations

a These instruments have one limitation which may or may not be serious depending upon circumstances If the temperature of the water becomes progressively cooler (or progressively warmer, as just under ice cover) as the depth increases, correct readings will result if the proper side of the thermometer is read, but if, as occasionally happens, an uneven layering of the water occurs in which the temperature change is reversed locally the reading for the still lower position may be a false one This limitation, which cannot be remedied, has led to the rejection of the instrument by some workers Certainly, it cannot be used with confidence except on those waters whose temperature behavior is known to be progressive in the vertical direction. It should not be used in any kind of reconnaissance work and it should be avoided in waters manifesting density layering or irregular mixing.

b. Subsurface readings made during the spring, summer and autumn will be taken from the left (cold) side of the thermometer since such

temperatures will all be above 4° C. and will ordinarily be progressively colder with increasing depth However, an exception should be noted if the thermometer is to be read and set in air On all occasions when the air temperature is *colder* than the surface water, it will be necessary to set and read the right side (warm) of the instrument until water temperatures are reached which are as cold or colder than the air, then read on the cold side (left). Or if preferable, read and set the thermometer just under the surface of the water, i e, do not bring it out into the air until water is reached which is as cold as the air, then all readings may be made on cold side

c To measure subsurface temperatures below an ice cover proceed as follows (1) if air temperature at time of reading is below zero and if the instrument is to be read in air, read all subsurface temperatures on the right hand side (warm), (2) if air temperature is higher than the temperature of the water just under the ice, submerge thermometer and set indices under water, then read temperatures for successive depths on right (warm) side and do not remove instrument from water but set indices by submerging magnet.

d Store instruments of this kind in an upright position

e If the mercury column becomes separated, grasp the instrument firmly by the upper end and swing vigorously and sharply downward in the arc of a circle until mercury unites

f If an index gets into the mercury, follow the directions just given in paragraph (e) above but in addition use the magnet and draw the index up as far as possible after first few swings until it is above mercury column.

g. If the index has been forced into the right reservoir, hold frame upright and manipulate index by tapping the frame gently and by using the magnet until it is drawn into the capillary tube.

Heat Budget of Lakes

Three different things are included under the term *heat budget* of a lake (a) the amount of heat required to raise the water of a lake from 0° C to the maximum summer temperature (*gross* or *crude heat budget*), (b) the amount of heat required to raise its water from the minimum winter temperature to the maximum summer temperature (*annual heat budget*), and (c) the amount of heat required to raise its water from 4° C. to the maximum summer temperature (*wind-distributed heat*, or *summer heat income*).

Since lakes do not have bottom temperatures as low as 0° C., the first statement is of least importance The second statement, representing as it does the two limits of heat content for the lake under consideration, is fundamentally the most valuable of the three approaches However, it involves the necessity of having available the necessary winter temperature

data. The third approach is useful only for *temperate* lakes whose winter temperatures are unknown.

Heat budgets may be computed as follows (a) the number of calories required to warm a water column of unit base in the deepest part of a lake from a selected minimum (0° C, 4°, winter minimum) to the maximum summer temperature, (b) the number of calories required to warm the whole water mass of a lake from the selected minimum to the maximum summer temperature; and (c) the number of calories required to warm a water column of unit base and a height equal to the *mean depth* of a lake from the selected minimum to the maximum summer temperature.

Heat budgets may be computed, when the lake is considered as a unit, by the following formulas.

Annual heat budget $= Dm\ (Tm^{s} - Tm^{w})$
Wind distributed heat $= Dm\ (Tm^{s} - 4)$

in which Dm is the mean depth of the lake *in centimeters;* Tm^{s} is the mean summer temperature, Tm^{w} is the mean winter temperature, and 4 represents 4° C. The results are expressed in *gram calories.*

Mean Temperature of Lakes

A satisfactory method (Birge, 1915) of computing *mean temperature* of a lake is as follows Make a vertical series of temperature records from surface to bottom at the deepest part of the lake; compute the *mean temperature of each stratum* bounded by each pair of adjacent records by the use of the formula $\frac{T_1 + T_2}{2}$ in which T_1 is the temperature of the upper limit of the stratum, T_2 is temperature of the lower limit of the same stratum Multiply the mean temperature of each stratum of the lake by the per cent of the volume of the whole lake which that stratum composes. The sum of these products represents the *mean temperature.* The whole computation is represented in the formula

$$T_m = \frac{T_1 + T_2}{2}(P_1) + \frac{T_2 + T_3}{2}(P_2) + \text{———} + \frac{T_{n-1} + T_n}{2}(P_n)$$

in which

T_m is mean temperature

T_1, T_2, T_3 is temperature at respective levels bounding the various strata of water

T_n is temperature at lowermost level of last stratum

P_1 is that percentage of the entire lake volume which the first stratum constitutes

P_2 is that percentage of the entire lake volume which the second stratum constitutes

P_n is that percentage of the entire lake volume which the lowermost stratum constitutes

According to Scott (1916) the method described above gives satisfactory results for lakes with steep slopes of basin but for lakes with *gently sloping sides* the mean computed below is the true one Therefore, he proposed the following formula to yield more accurate results

$$T_m = \frac{(3A + 2\sqrt{AB} + B)\ (T_1 - T_2)}{(A + \sqrt{AB} + B)\ 4} + T_2$$

in which this computation is repeated for each stratum of the lake and the sum taken to represent mean temperature, and in which

T_m is mean temperature
T_1 is temperature at the upper level of the first stratum
T_2 is temperature at the lower level of the first stratum
A is area of upper level of first stratum
B is area of lower level of first stratum

Thermal Resistance

Birge (1916) supplied the following formula for the computation of the work done in mixing a column of water of unit base and height and a uniform temperature gradient

$$W = \frac{AC^2}{12}\ (D_2 - D_1)$$

in which
W is work in ergs
A is area of cross section of water column
C is height of water column
D_1 is density of water at upper surface of water column
D_2 is density of water at lower surface of water column

If A and C are assumed to be constants, as for example, 1 sq cm and 100 cm., respectively, the thermal resistance will depend upon the value of $D_2 - D_1$, or, to express it another way, $(1 - D_1) - (1 - D_2)$. In limnological work it is convenient to assume A as 1 sq. cm , C as 100 cm., 1° C. as the standard temperature gradient, and as the standard unit, the amount of work necessary to mix a 1 × 1 × 100-cm. column of water whose temperature is 5° at the top and 4° at the bottom Under these conditions W (work) = 0.0067 ergs, a value which can be accepted as the unit of work done in mixing (see Appendix, Table 7)

The unit of thermal resistance may also be taken as $D_4 - D_5$ which equals 0 000008 Then in any column of water 1 × 1 × 100 cm with a

uniform temperature gradient the number of units of thermal resistance is equal to $\frac{D_m - D_n}{8}$ in which m and n are the temperatures of the water at the two ends of the column (see Appendix, Table 7, Column IV).

Work of Wind in Warming a Lake

According to Birge (1916) the work of the wind in warming a *stratum* of a lake, by mixing, from 4° C to any selected temperature may be computed by means of the formula

$$W = RT \times Z \times (1 - D_n)$$

in which

W = work expressed in gram-centimeters per square centimeter of surface of lake

RT = reduced thickness = thickness of stratum if its area is made equal to that of lake and its sides vertical, computed from formula $\frac{V_{n-m}}{A_0}$ in which A_0 = area of lake at surface, V_{n-m} = volume of stratum between two selected levels, reduced thickness expressed in *centimeters*

D = density of water, D_n = density of water at any selected temperature, at 4° C, D equals 1, but less than 1 at all other temperatures

Z = distance from surface of lake to middle of stratum expressed in centimeters

Computation of work for an entire lake can be made by adding the results from all of the various strata used from surface to bottom of the lake. If accurate results are needed, the computation should be based upon successive strata, each 1 m thick, for the entire depth of the lake.

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TURBIDITY

UNIT OF MEASURE The standard unit for measuring turbidity is that condition produced by *one part per million* of silica (fuller's earth) in distilled water.

Formerly, the U S Geological Survey defined the standard of turbidity as that water containing 100 parts per million of silica the state of fineness of which is such that a bright platinum wire 1 mm in diameter can just be seen when its center is 100 mm below the water surface and the observer's eye is 1 2 m. above the wire, the observation being made at midday, in open air but not in direct sunlight, and in a vessel of such size that its sides do not shut out the light so as to influence the results. The turbidity of such water is given the value of 100 This standard is merely 100 times greater than the unit defined in the preceding paragraph and is based upon the same system of measurement (parts per million)

Methods for the measurement of turbidity in natural waters usually fall into three classes (a) comparison with silica standards, (b) platinum wire method; and (c) turbidimetric methods. The first two classes represent somewhat older practices, have certain limitations, and for many kinds of work are now often replaced by turbidimetric methods

COMPARISON WITH SILICA STANDARDS

It is possible to secure from commercial scientific companies permanent turbidity standards already prepared and ready for use. They are available for various graded values and unless a laboratory is supplied with facilities for making standards it is preferable to secure them in this way. However, if standards are to be prepared, proceed as follows To 1 l of distilled water add 5 g. of standard fuller's earth; mix thoroughly, repeat this mixing periodically for about one hour, then let stand undisturbed for 24 hrs , carefully draw off the supernatant fluid, being cautious that settlings at the bottom of the bottle are not brought back into suspension, test this supernatant fluid by the platinum wire method or by a standard turbidimeter (see p. 132) to determine its turbidity value Take various portions of this liquid and by additions of distilled water adjust each portion to some desired turbidity value in the range of 5–100 p. p. m., testing the accuracy of each dilution by means of the platinum-wire method or by a turbidimeter. For general purposes a series having the following values will be convenient 5, 10, 15, 20, 25, 30, 40, 50, 60, 70, 80, 90, 100. Nessler tubes

of uniform size and glass, having a capacity of 100 cc. and a diameter of 20 mm., are suitable containers for these standards

In operation, put the sample of unknown value in a glass tube like those containing the standards, shake thoroughly both sample and standard, hold sample and standard side-by-side and observe both sidewise toward the light, looking at some convenient object and noting the relative distinctness of the outlines of the object, match various standards with the sample until close correspondence is obtained. When the two tubes agree, the turbidity value of the unknown is that of the standard which matches it Experience seems to show that there is some advantage if the object observed is a series of black lines ruled on white paper, if the light used is electric, and if the light illuminates both sample and standard from above, no direct rays reaching the eye of the observer

GENERAL CONSIDERATIONS

a It is recommended that silica standards so prepared be made up fresh at least every month.

b. Standards should be put into clean glass containers and kept well stoppered Leave enough unoccupied space in the top of the container to provide for adequate shaking and mixing.

c. A small quantity of mercuric chloride added to the standards will serve to prevent growths of bacteria and algae

Platinum-wire Method

The platinum-wire method is operated through the use of an instrument constructed essentially as follows A piece of straight, bright platinum wire, 1 mm. in diameter and about 25 mm long, mounted in a detachable screw eye, is set into the end of an aluminum scale, 21 cm in length, in such a way that it projects at a right angle. At a distance of 1 2 m above the platinum wire a mark is placed on the tape to indicate the position of the observer's eye when the instrument is being used At exactly 100 mm above the center of the wire the graduation mark of 100 is placed on the aluminum scale and other graduations are established above and below the 100 mark in accordance with standard data on the vanishing depths of the wire and their turbidity values Probably the best known form of platinum-wire turbidity apparatus is that known as the U.S Geological Survey turbidity rod (Fig 33) in which the lowermost portion is a flattened bar, 6 × 17 mm in transverse section, 21 cm long, and composed of nonrust metal On one face of this bar occurs that portion of the graduated scale extending from 3000 to 50 Into the end opposite the platinum wire there is securely fastened a piece of light-colored waterproofed, strong, inelastic cloth tape on which graduation marks 47 to 7 and the eye-position mark occur

In operation, the end of a slender stick or rod is inserted into the hole of the screw eye Then holding the tape taut, the scale is lowered vertically into the water to be tested as far as the platinum wire can be seen when the observer's eye is kept at the proper position When the wire fades from view the surface level of the water on the rod is read on the graduated scale and the value thus obtained is a measure of the turbidity in terms of parts per million In order to secure as accurate results as possible the

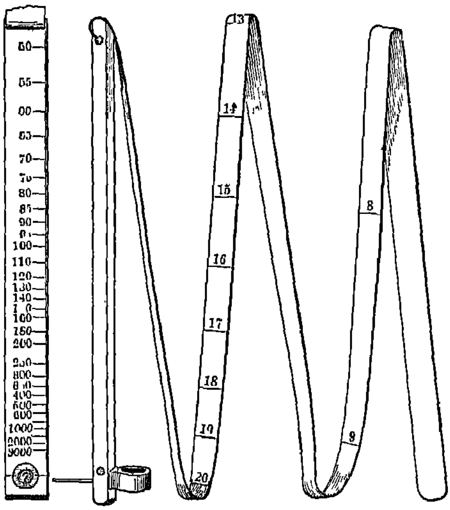


FIG 33 U S Geological Survey turbidity rod (Reprinted by permission from "The Microscopy of Drinking Water," by Whipple, Fair, and Whipple, published by John Wiley and Sons, Inc)

following practices should be followed (1) Make all observations in the open air, preferably near midday, but not in direct sunlight, (2) keep the platinum wire clean and bright, (3) if measurements must be made remote from the natural conditions under which the water normally exists, fill a tank of proper dimensions with the water to be tested and make measurement, stir the water thoroughly before the test is made (use a tank having horizontal dimensions at least twice as great as the depth to which the platinum wire is to be submerged), make measurements under conditions described above, and (4) dilute waters having a turbidity exceeding 500 p p m with clear water, make reading on diluted sample, then compute the turbidity of the original sample from the dilution data

GENERAL CONSIDERATIONS

a This instrument has the virtues of low cost, light weight, and very small bulk.

b This instrument has the following limitations (1) The working range is approximately 7 to 500 p p m, (2) it is essentially a field instrument, if used in the laboratory very large samples are required, especially in the clearer waters, (3) since the use of the instrument depends upon limit of visibility, different observers may secure somewhat different values for the same sample depending upon differences in eyesight.

c In field use, waves, ripples, and other forms of surface disturbance interfere seriously with the operation of the instrument and affect the dependability of results If the rod must be used under these conditions much of the difficulty may be removed by viewing the descending rod through a water telescope (pp 363–364) so held that surface disturbance is eliminated, or a tank may be used as described previously (p 129)

d. In its conventional form, the U.S. Geological Survey turbidity rod lacks provision for a safety tie-on If the rod is to be used in the field over deep water it is imperative that some safety device be added to insure against loss

e This instrument may serve a useful function in providing a means of checking turbidity values of silica standards, both in the making up of new silica standards and in checking for changes in such standards with aging

f. Avoid making measurements under a roof since values so secured are too high, even with very good light

JACKSON TURBIDIMETER

The Jackson turbidimeter may be used to measure turbidities having a value greater than 25 p. p. m It operates on the principle that the depth of a column of any turbid liquid necessary to make the image of a flame of a standard candle disappear when viewed vertically through the column is a measure of its turbidity The instrument (Fig 34) consists of a substantial base from the center of which a brass candle holder extends vertically. The base also supports in tripod fashion and at the proper height a hollow metal tube holder in which a graduated glass tube is carried. Tube holder and candle holder are both so aligned that the middle long axis of the candle when in place coincides exactly with the middle vertical axis of the graduated tube. Installed in the candle support is a spring device which keeps the top of the candle at the same required level at all times, namely, 7 6 cm below the bottom of the superimposed glass tube The glass tubes have flat, polished bottoms, and are graduated to read directly in turbidity

units of parts per million. The standard candle is made of beeswax and spermaceti and constructed to burn at the rate of 114–126 grams per hour.

To operate, place a standard candle in the holder in proper position, put a graduated glass tube of length suitable for the particular sample to be measured in the holder above the candle, darken the room, light the candle and pour sample into the graduated tube meanwhile viewing the candle flame from above and through the column or sample, continue pouring until image of candle flame barely disappears Pour very slowly as end point is approached. If proper care has been exercised in determining disappearing point, the removal of one per cent of the sample should cause the candle image to reappear The turbidity value in p p. m. will be read directly on the graduated scale, determined by the top level of the sample in the tube

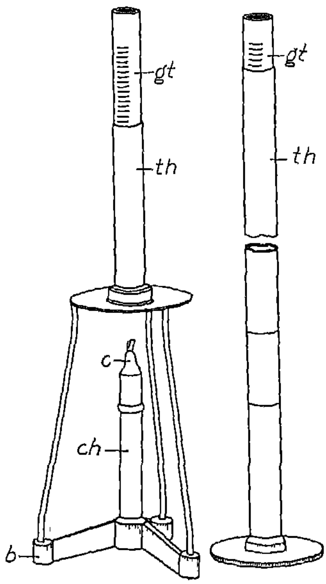


FIG 34. Jackson turbidimeter (*Left*) Assembled instrument. (*Right*) Extension tube for the use of a 75-cm. graduated glass tube. (*b*) Tripod base (*c*) Uppermost tip of candle. (*ch*) Hollow, metal tube holder for candle (*gt*) Graduated glass tube. (*th*) Hollow metal tube holder for graduated glass tube

PRECAUTIONS. Keep candle lighted for only a few minutes at a time, the flame tends to increase in size as it continues to burn Be sure that the spring mechanism is functioning continuously and that the tip of the candle is kept at the proper distance from the bottom of the glass tube. Keep candle well trimmed and all charred portions of the thread removed. Be careful that bottom of glass tube does not become hot before sample is poured into it. Do not permit the water to acquire heat while running test. Keep glass tubes clean both inside and outside. Make certain that soot and moisture are cleaned off the lower surface of the glass tube since any accumulations there detract from the accuracy of the readings See that air currents in the room are reduced to a minimum.

GENERAL CONSIDERATIONS

a If a darkroom is not available, a black cloth over the head of the observer will make readings possible

b The metal tubes should be black on the inside to prevent light reflection.

c. The standard 25-cm glass tube, graduated in millimeters on one scale and p. p m on another, is used for samples in which the turbidity is

greater than 100 For turbidities less than 100, an extra long (75-cm.) graduated glass tube in a metal extension is used.

d. The advantages of the Jackson turbidimeter lie in modest cost, ease of operation, and absence of any requirement for electric current or silica standards.

Hellige Turbidimeter

The Hellige turbidimeter is used to measure directly turbidities of 0–150. Higher turbidities may be measured by diluting the sample with

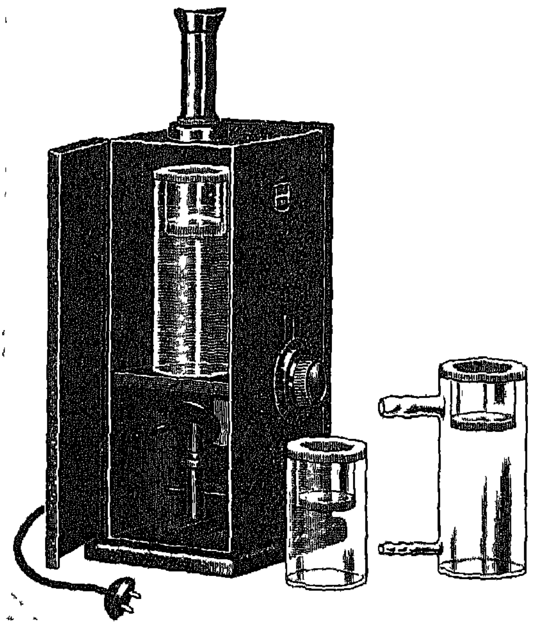


Fig 35. Hellige turbidimeter. (*Left*) Shown with door of turbidimeter open, tube and plunger in place as in actual test (*Right*) Tube with side arms for connecting to water line in order to provide continuous turbidity readings (plunger in place) (*Center*) Short tube, with plunger in position, for use with more turbid liquids. (Courtesy, Hellige Inc, Long Island City, N Y)

zero-turbid water and calculating the original turbidity from that of the diluted sample This turbidimeter is particularly useful because of its capacity for measuring very low turbidities with high precision The principle on which it operates consists of the comparison of a beam of light with the Tyndall effect produced from the lateral illumination of the

sample by the same source of light. Thus no standard suspensions are necessary. Figs. 35 and 36 show the essential features of construction of the instrument. Light rays from the opal-glass bulb *b* are reflected from the reflector *r* into the sample in the glass tube *t*. This lateral illumination of the suspended particles in the sample produces the Tyndall effect. Light rays are also transmitted from the lamp *b* through a precision slit *s* operated by a graduated drum knob on the outside of the housing of the whole apparatus. Light rays passing through this precision slit illuminate the milk-glass reflector, thence they are reflected vertically through a filter plate *fp*, then through a circular opening in the horizontal silver mirror *m*, thence through the sample in the glass tube *t*, on through the glass plunger *p* and then into the ocular *o* to the eye of the operator. These light rays appear to the observer as a circular spot in the center of the Tyndall effect of the illuminated sample. This circular spot will appear

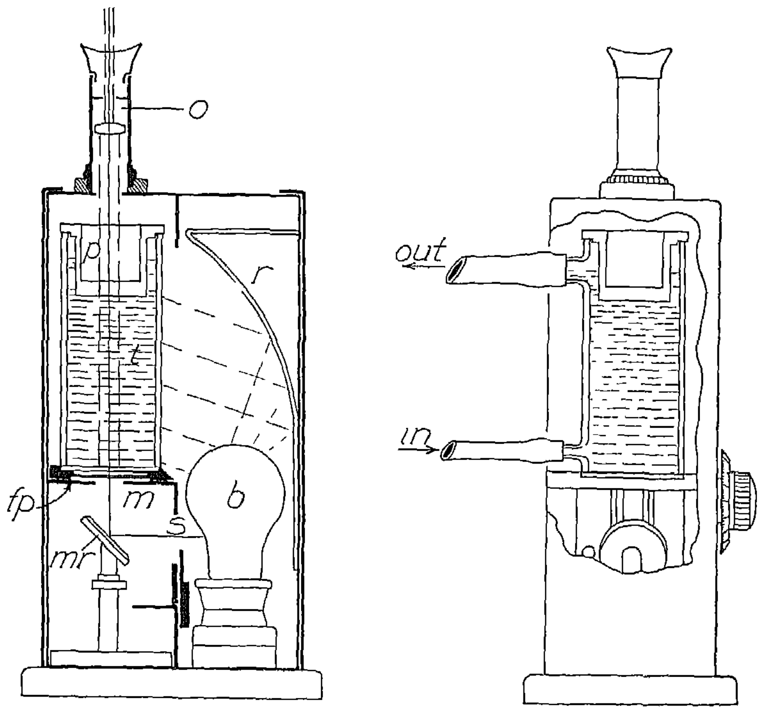


FIG. 36. Hellige turbidimeter. (*Left*) Sectional view showing details of internal construction. (*Right*) Diagram showing use of special tube with side arms for connection with water line so that continuous turbidity readings can be made without necessity of filling tube for each sample. (*b*) Opal-glass bulb. (*fp*) Filter plate. (*o*) Ocular. (*p*) Glass plunger. (*m*) Mirror. (*mr*) Milk-glass reflector. (*r*) Large reflector. (*s*) Adjustable precision slit. (*t*) Specimen tube. (Courtesy, Hellige Inc., Long Island City, N. Y.) (Redrawn.)

lighter or darker than the Tyndall effect depending upon the size of the precision slit. With the operator's eye at the ocular, the graduated dial may be so manipulated (adjusting the opening of the slit) that the circular spot and the surrounding illumination come to have the same degree of brightness, thus obliterating the circular spot. When this adjustment point is reached, its position on the drum scale is read This value is then applied to a table or curve provided with the instrument and the turbidity is read, without calculation, directly in parts per million.

The glass tubes for holding the samples are made for sample depths of 20, 50, and 100 mm. These tubes have sealed-on plano-parallel bottom plates of optical glass The upper end of the tube, when filled with a sample, is capped with a short glass "plunger" which automatically adjusts the proper depth in the sample and is usable in all sizes of tubes.

Guidance in the selection of the proper sample tube, turbidity range, and for use or nonuse of filter plates is supplied in the following tabulation.

Tube No	*Sample Depth of Tube*	*Approximate Range in p p m SiO_2*	*Filter Plate Used*
8010-A or B	100 mm	0–4	gray glass
8010-A or B	100 mm.	0–15	milk glass
8010-C	50 mm.	0–50	none
8010-D	20 mm.	0–150	none

To operate, select a *thoroughly clean* (outside and inside), glass specimen tube whose length is suitable for the turbidity of the sample, fill tube with sample to level slightly higher than liquid level marked on the tube, close upper end by insertion of *clean* glass plunger, eliminate all gas bubbles in sample or on glass. Place glass tube containing sample in the instrument housing, on the mirror frame and in the circular depression, set filter plate in correct position, close door of housing and switch on light. Set graduated dial at zero. With eye at ocular, revolve dial in direction of increasing values until spot in center matches surrounding area (spot disappears). Read dial and determine turbidity from value thus obtained.

Adjustment of the light fields will probably not be an end point, but rather an *end interval* over which the light fields appear to be balanced. This interval will be larger at higher scale readings To reduce some of this uncertainty, all adjustments should be made by always turning the dial toward the increasing values until the central spot just disappears, i e, the reading should be taken when the end interval is first entered

GENERAL CONSIDERATIONS

a The whole operation of filling the glass sample tube, the insertion of the sample tube in the instrument, and the adjustment of the dial should

be done as quickly as possible to avoid settling of suspended particles to the bottom and convection currents due to heating by the lamp.

b. All parts of the instrument, particularly the glass specimen tube and the plunger, must be scrupulously clean inside and outside. The glass tube and plunger may be cleaned with soap solution but *never* should strongly acid or alkaline cleaning mixtures be used. As the last step in the cleaning procedure, rinse with clean water and a portion of the sample to be tested. Avoid use of cloth, it is too likely to leave lint on the surfaces. One of the best means of removing water from the outside of the sample tube after filling is a cellulose sponge of the type used in cleaning photographic films. Such a sponge should be kept clean and submerged in distilled water in a closed jar during active use; at end of work it should be dried thoroughly in open air. Clean the silver mirror and filter glasses with soft cloth. Clean milk-glass reflector under the mirror with soap solution

c. In order to avoid fingerprints on the outside of the sample tube at a place where they would interfere, it should be handled by grasping it at the top above the level of the bottom of the plunger.

d Each opal-glass lamp bulb must be individually gaged and provided with its own set of graphs. This fact must be kept in mind when new bulbs are ordered

e. Gas bubbles on the lower surface of the plunger may be avoided by putting it into the glass sample tube so tilted that one edge of the plunger makes the first contact with the upper surface of the sample, then as it is introduced further into the water the whole plunger bottom should be settled into final position with a side motion

f. Be sure that the filter plate is in the proper position when a sample is being tested, otherwise, serious error will occur.

g. Glass sample tubes and the plunger must be handled with great care. Always put them down on some soft, clean material (a rubber pad is recommended) to avoid breakage or scratching. Do not submit the cemented joints to undue mechanical strain, such strains may cause the bottoms to become unsealed.

h In case it is desired to measure turbidity continuously in flowing water, a sample tube of 100-mm. liquid depth (Fig. 36) can be secured which has two side arms that may be connected by rubber tubing to the water supply in such a way that the water changes continuously in the sample tube. This arrangement avoids the necessity of filling and emptying the tube for each sample

i. The advantages of this instrument are (1) avoidance of the use of standard turbidity suspensions or standard candles, (2) high accuracy in the low end of the turbidity scale, (3) simplicity and speed of operation, (4) avoidance of need of a darkroom, and (5) compactness and portability.

Other Methods

The Baylis turbidimeter (Baylis, 1926) is now used to considerable extent, especially in sanitary work A transparency meter for measuring transparency and scattering properties of water *in situ* at various levels in a lake has been developed by Whitney (1938)

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(For Chapter 8)

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COLOR

By *color* in water is meant those hues inherent within the water itself which result from colloidal substances and materials in solution. The term *true color* is sometimes used to designate color due to these causes.

Platinum-cobalt Method

Unit of Measure. That color produced by 1 mg of platinum in 1 l. of distilled water.

Standards Dissolve 1 245 g. of potassium chloroplatinate (K_2PtCl_6) and 1 g of crystallized cobaltous chloride ($CoCl_2 \cdot 6H_2O$) in small quantity of distilled water, add 100 cc. concentrated hydrochloric acid and dilute to 1 l with distilled water A solution so prepared has a color value of 500

Prepare standards having color values of 5, 10, 15, 20, 25, 30, 35, 40, 45, 50, 55, 60, 65, and 70 by diluting 0 5, 1 0, 1.5, 2 0, 2 5, 3 0, 3 5, 4 0, 4 5, 5 0, 5 5, 6 0, 6.5, and 7.0 cc of solution described above with distilled water to 50 cc in standard Nessler tubes Or, if desired, use 100 cc standard Nessler tubes, double all values 0 5, 1.0, 1 5, etc , and dilute each to 100 cc with distilled water and same series of color values mentioned above will result Label each tube, indicating color value and date of preparation

PROCEDURE

Put sample through high-speed centrifuge to remove suspended matters Fill standard Nessler tube with sample to be measured and to same height as that of standards Compare it with various standard tubes until one is found which has same hue as unknown. Make this comparison by looking down through tubes held vertically and placed side by side above a white or mirrored surface so oriented that light is reflected upward through tubes Results are read directly in parts per million

GENERAL CONSIDERATIONS

a. If the sample shows a color greater than 70 it should be diluted with distilled water so that the comparison of hues may be facilitated. The original color is then computed on the basis of the amount of dilution

b Do not use filters for the removal of suspended matters since filtering tends to produce a decolorizing effect

c Color of an uncentrifuged sample (sometimes referred to as *ap-*

parent color) may be determined if desired but the limitation of such a measurement should be understood

d. When not in use, standard tubes must be protected from dust and evaporation.

Glass-disks Method

A convenient method for measuring color of water is that in which colored, nonfading glass disks serve as standards These disks are individually calibrated to correspond to the platinum-cobalt scale Such a set

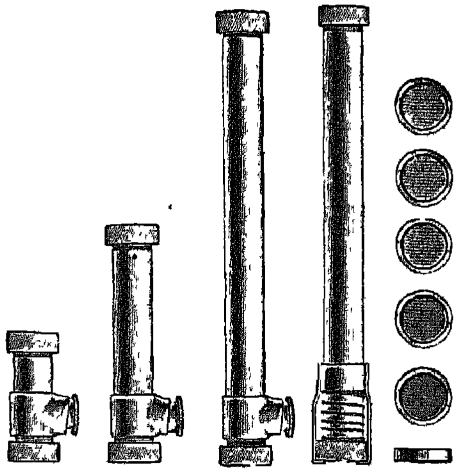


Fig 37 U S Geological Survey outfit for measuring color of water. (Courtesy, Precision Scientific Co, Chicago, Ill.)

devised for the U.S Geological Survey (Fig. 37) is now recognized as standard equipment for this purpose Each glass disk is mounted in an aluminum ring. On each ring is stamped the color value of the enclosed glass disk, a serial number is also stamped on this rim A standard set usually consists of 5 or 6 disks In addition to the series of glass disks, such an outfit includes three aluminum tubes (sample tubes) having lengths of about 5, 10, and 20 cm, and capacities of about 10, 20, and 40 cc, respectively, and each tube is equipped with removable glass ends and with side filler openings A fourth aluminum tube (standard tube), in addition to removable glass ends, also has a spring holder at one end for the temporary attachment of the glass disks.

PROCEDURE

1 Either fill *standard* tube with distilled water or, if more convenient, carefully clean inside of tube, removing all water to prevent fogging of glass ends, and use tube empty.

2 Fill one *sample* tube with water whose color is to be measured, selecting a tube of suitable length depending upon color character of sample.

3 Hold sample tube and standard tube parallel and in contact and at such a distance from observer's eye (about 8–10 in.) that inner surfaces of tubes are practically invisible View tubes through eye-piece ends (glass disks of smaller diameter). Be sure to hold both tubes at such position and at such angles that both can be *looked through simultaneously with one eye*

4. Interchange tubes in position and determine if light on right and left is approximately equal, equality of illumination is required. On a cloudy day, look through pair of tubes at sky near horizon and away from position of sun, on clear day, look at piece of white paper, white tile, or other similar white surface on which strong light is shining.

5 Slip colored, standard glass disks, singly or in combination, in spring holder on standard tube until by repeated trials, holding tubes as described above, color in both tubes matches. If this result is attained by one disk, color value can be determined at once from color number stamped on metal rim. If disks in combination are necessary, color value is determined either from color ratio of disks used, or from use of serial numbers on rims in transformation table. Some sets of standards are made in such a way that each disk has definite ratio to next one in series so that disks may be used in combination and combination value read directly, as for example, number 10 and number 15 glass used in combination give color value of 25.

The directions given above hold only for waters having a color value less than about 80. Waters having a color value in excess of 80 should not be matched in the 20 cm. tube but instead should be tested in one of the following ways·

a. Use one of shorter sample tubes (10 or 5 cm.) depending upon color depth of water to be tested. Match shorter tube against same standard tube mentioned above However, do not fail to observe necessary computation step in arriving at true color value, namely, result obtained with the 10 cm tube must be multiplied by 2, that secured with 5 cm tube must be multiplied by 4.

b Dilute sample with number of known volumes of distilled water, match with standard disks as described above; multiply result by number of volumes of distilled water used as dilutant In preparing dilution of

original sample, use tube itself for measuring sample and distilled water, mixing both in any convenient, clean container.

GENERAL CONSIDERATIONS

a. Do not make color measurements by this method under artificial light since dependable results cannot be obtained.

b. When first purchased, standard glass disks should be checked against platinum-cobalt standards.

c Low turbidity does not interfere with this kind of color measurement. Highly turbid waters require filtration through thick filter paper before color tests are made. However, it is sometimes of considerable value to have a turbidity measurement of the unfiltered sample before it is put into the color sample tube.

d Because of their size and shape, the color disks must be guarded carefully against loss in the field

e Tubes and disks must be kept scrupulously clean, also dry when not in use Lens paper or a soft cloth free from oil may be used for cleaning glass disks

f The glass ends on the tubes must be handled carefully, avoid forcing them on too tightly

g. In field work this method is very convenient but usable only when color measurements of unfiltered samples are acceptable

h If tubes have not been used for some weeks or months the packing materials in all movable joints should be soaked in water for several hours prior to use in order to prevent leakage

WATER MOVEMENT

Current Velocity

Of the various devices for measuring velocity of flowing liquids, certain ones may be adapted to the needs of limnology All have limitations which must be fully understood

PITOT TUBE

In its simplest form a Pitot tube is an L-shaped glass tube (Fig. 38) with both ends open When it is suspended vertically with the shorter end submerged in flowing water and pointed upstream, water enters the open end at e and rises a distance h above water level outside If the water flow is steady, height h of the water column within the tube remains practically constant, irregularities of flow cause fluctuations in h The height h is a measure of velocity of the water at or very near e and assuming stream-line motion of the water outside and ignoring friction, this velocity is computed as follows·

$$v = \sqrt{2gh}$$

in which v = velocity, h = height of column in tube above general water level outside, and g = acceleration of gravity

Under certain circumstances it is possible to adapt such a simple Pitot tube to limnological needs It may be made by bending ordinary laboratory glass tubing in a flame and marking a suitable, easily readable set of graduations on the vertical arm. When so constructed the following formula provides an average constant (0.977) which represents more precise results

$$v = 0.977\ \sqrt{2gh}$$

If the velocity is desired in terms of feet per second, then v = velocity in feet per second, g = 32 16 ft. per sec , and h = height of water column, in fractions of a foot, in tube above general water level. If it is desirable to take capillarity into account, the upper end of the tube may be dipped into water, the rise of water due to capillarity measured, and this value subtracted from h

In its simplest form, as described above, the Pitot tube is sometimes difficult to use In quietly flowing water with not too great velocity, h may be measured with some ease and accuracy. However, in waters of

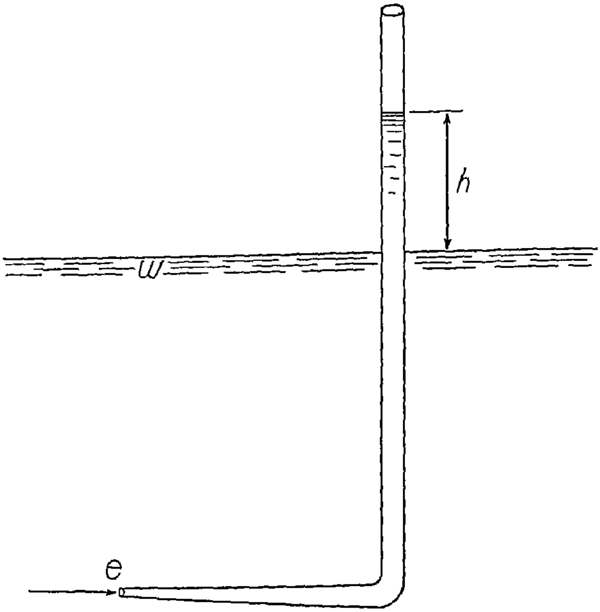
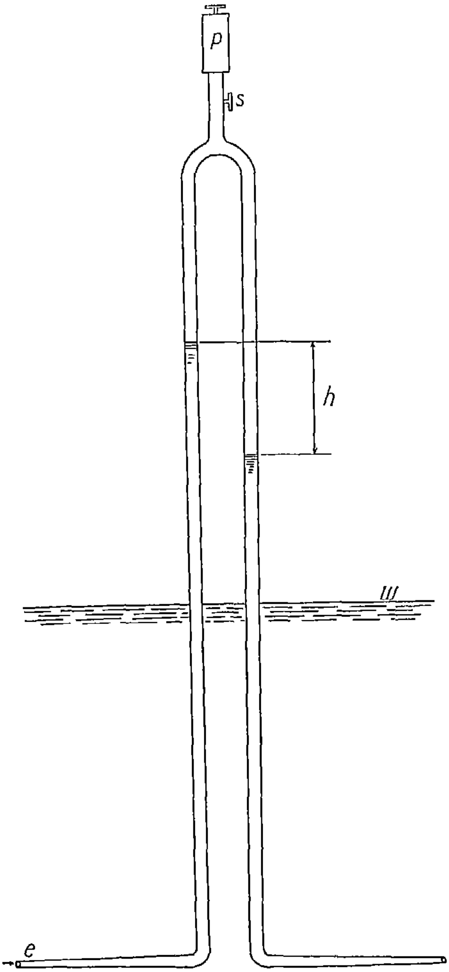


FIG 38. Pitot tube in simplest form (*e*) Point of entrance of flowing water. (*h*) Distance between water level inside of tube and outside water level (*w*) General water level. Arrow at *e* represents direction of water flow

high velocity or currents with much surface disturbance, the measurement of *h* is difficult, uncertain, and sometimes virtually impossible.

IMPROVED PITOT TUBES

Many modifications in and additions to the simple Pitot tube have been made in order to overcome difficulties and extend its use to flowing waters in general. An early improvement appears in Darcy's instrument which consisted of two duplicate L-shaped tubes built together as shown in Fig. 39 One tube is pointed upstream, the other downstream. Both are connected at their upper ends to a single tube which is provided with a closing valve *s* and which terminates at the top in a small plunger pump. When *s* is opened and the lower portions of the instrument are submerged in water to the desired depth the air in the upper portion of the tubes is partly pumped out, allowing the water to rise above the outside water level. The water will rise higher in the upstream tube than in the downstream one and the difference in level *h* has a constant relation to the actual velocity of the water at the point tested. This device eliminates the effects of surface disturbance by putting both levels to be read above the water line However, it should be noted that the downstream arm does not provide a



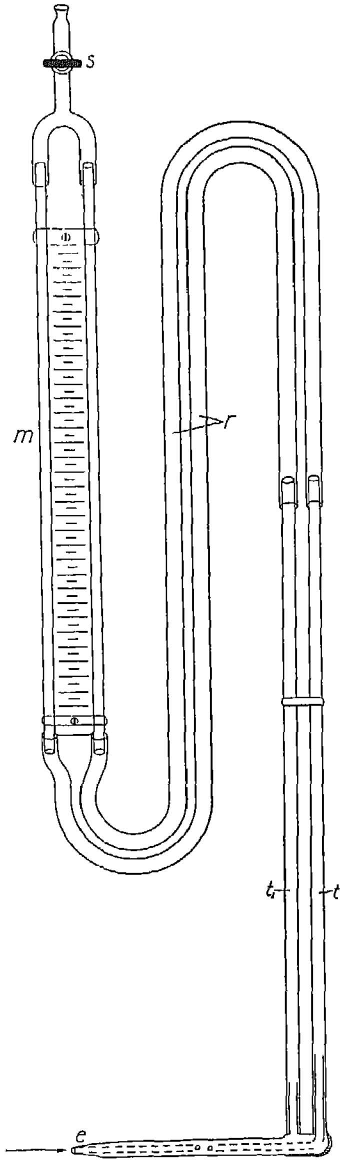


Fig 39 (*Left*) Darcy's modification of the Pitot tube (*e*) Point of entrance of water (*h*) Difference in height of water levels in two arms of instrument (*p*) Pump (*s*) Stopcock (*w*) General water level

Fig 40. (*Right*) Diagram of the essential features of a modern, simple form of Pitot tube (*e*) Point of entrance of flowing water (*m*) Manometer. (*r*) Rubber tubing connecting two arms of Pitot tube with manometer (*s*) Stopcock (*t*) Tube registering rate of flow of water (opening at *e*). (t_1) Tube registering hydrostatic pressure, opening to outside through two small lateral pores Arrow indicates direction of water flow

true measure of the general static pressure in the water and hence h cannot be used directly in the formula mentioned above In order to secure values for determining current velocity, each instrument must be tested in a rating canal or by some other experimental means.

An improved but relatively simple Pitot tube is illustrated in Fig 40. It consists of two tubes so arranged that one, t_1, indicates the static pressure (normal water level) and the other, t, the sum of the static pressure and the velocity pressure, the difference between the two being the height h in the formula stated above. On each side of the lower horizontal arm two small openings lead into a space continuous with that in t_1. The opening at e leads directly into a closed tube which in turn leads into t When in operation the two tubes are connected to a manometer by means of two rubber tubes of suitable length The manometer consists of two glass tubes of equal diameter and length mounted on the two sides of a graduated scale These two tubes unite at the top into a single tube which terminates in a stopcock When ready for use, the lower, horizontal arm is lowered into the water at the selected location and depth, and fixed in position by some stable form of support which will not interfere with the action of the instrument, the manometer is fixed above water to some convenient support, the stopcock at the top is opened and by means of suction applied at the upper end water is drawn into the manometer tubes until both are partly filled It may be necessary to determine by various trials the most favorable height of the manometer above the water surface and the most favorable height of the water levels in the tubes. The stopcock is then closed and if the instrument is free from leaks, a reading of difference in height h of the water columns in the manometer can be made at once When so measured, the height h may be substituted directly in the formula $v = \sqrt{2gh}$. However, manufacturers usually supply a set of curves for these instruments by means of which the velocity may be read directly as soon as the manometer reading is known.

When properly used, this instrument gives reliable results It has the disadvantage of being somewhat cumbersome for one person to use unless stable installation is provided by means of which both tube and manometer are immobilized. Consequently it is slower than certain other methods It has the advantage of simplicity in construction and can be built in any laboratory from simple materials Obviously, such an instrument is usable only in shallow water. It also shares with other forms of Pitot tube the limitation of being less effective in very low velocities It measures velocity at any instant, although the average velocity over a period of time may be secured by making a series of manometer readings at selected intervals during the total time period It also has the virtue of measuring velocity at a small area, i.e., the size of the tube at e, and this aperture may be

directed into various situations within a stream which are inaccessible to some other kinds of current-measuring devices

BENTZEL VELOCITY TUBE

The Bentzel velocity tube overcomes some of the disadvantages inherent in other current-measuring devices. It consists essentially of (a) a long metal tube in the shape of the letter U, with both ends bent through 90° and directed opposite each other, (b) a tapered glass or plastic tube with accompanying graduated scale in the upper part of one arm, (c) a priming device (usually a small air pump), and (d) an index (either a float or a sinker, depending upon the form of the instrument) in the tapered glass tube These features may be assembled in various ways

The principle on which this instrument acts is as follows When the instrument is held vertically, with the two oppositely directed orifices of the long U-shaped tube submerged in running water, the whole tube filled with water, and one aperture directed upstream and the other downstream, a flow of water through the instrument is established, entering one aperture and emerging from the other, due to the difference of pressure at the orifices Near the upper end of one arm is a tapering glass tube, a *dilator*, whose diameter increases in the direction of flow Within the dilator is a floating index, outside it is a half-cylinder rotating sleeve which bears on its concave surface a graduated scale. In one type of instrument, the dilator is in the downstream arm, its expansion is downward, and the index is lighter than water; in the other type, the dilator is in the upstream arm, its expansion is upward and the index must be heavier than water Fig 41 represents an instrument of the latter type. The description which follows relates to this type.

When in correct operating position, the water flowing through the dilator exerts a force on the index lifting it vertically The index comes to rest at some level, determined by the velocity of water flow, where the tractive force on the index just balances the weight of the index This level, read on the adjacent scale, is a measure of the water velocity. If the scale is an arbitrary one, actual velocity is determined by referring the scale reading to a rating curve supplied with the instrument, if the scale is graduated in terms of velocity units, the reading is direct

The velocity range of types now commercially available is 0 3–4 0 ft. per sec. (0.09–1.21 m.). However, with special indices, adjustments, and precautions, velocities as low as 0.15 and as high as 7 0 ft per sec (0.04–2 13 m.) are measurable. While depths to which velocity measurements may be made are usually limited to about 1 m , it is possible to build such an instrument so that greater depths may be studied

The advantages of the Bentzel velocity tube are as follows (a) general convenience, (b) ease of operation by one person, (c) mechanical ac-

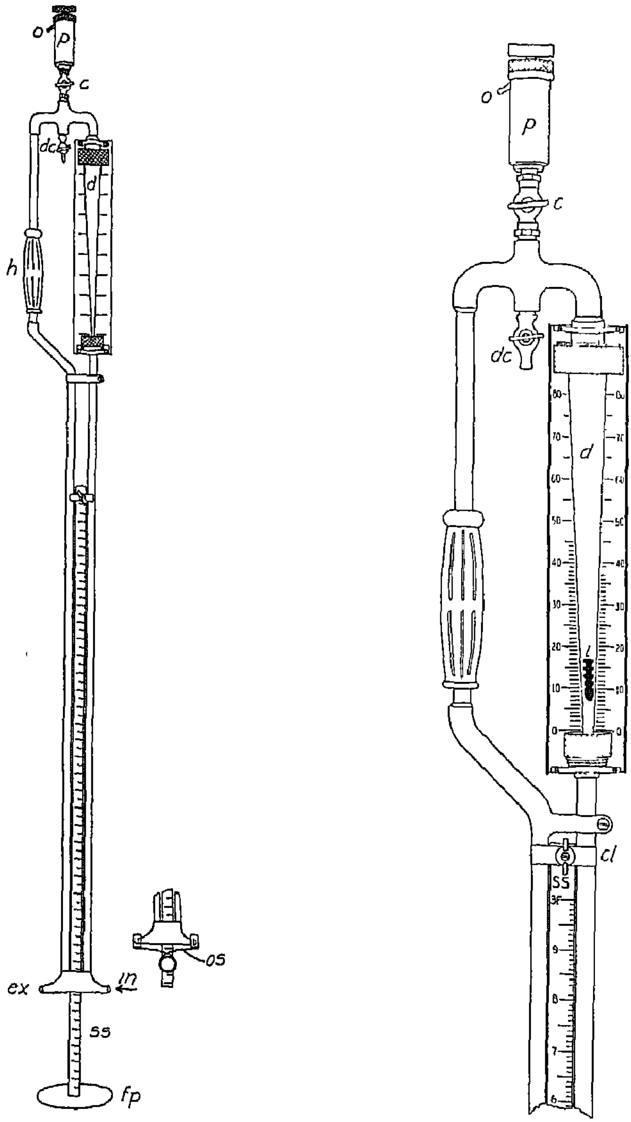


FIG. 41 (*Left*) Bentzel velocity tube, type with priming pump and sliding scale with foot plate, detail to right represents orifice stop in position, closing incurrent and excurrent openings (*Right*) Enlarged view of upper portion of velocity tube showing structure of dilator and associated scale (*c*) Stopcock (*cl*) Clamp for immobilizing sliding scale. (*d*) Dilator. (*dc*) Drain cock. (*ex*) Excurrent opening (*fp*) Foot plate (*h*) Handle. (*i*) Index. (*in*) Incurrent opening. (*o*) Pump overflow (*os*) Orifice stop. (*p*) Priming pump. (*ss*) Sliding scale

curacy to about 2 per cent, (d) sensitivity to low velocities, (e) measurement of both velocity at any instant and mean velocities over a period of time, (f) rapidity of measurements, (g) mechanical supports not required, (h) measurement of velocity at very small spot and at situations very near the bottom, and (i) usability in vegetation beds, regions of coarse debris, or in streams full of rocks and obstructions

General Considerations

a Since it is not possible at present to manufacture dilators which are exact duplicates, every dilator must be calibrated independently together with the index to be used in it.

b. Temperature of the water produces an effect on the rating but the change is so slight that it can usually be disregarded within the velocity range mentioned above.

c. All air bubbles must be removed from the index before records are made since they affect the rating

d The index will give correct readings only if the proper end is up. If the index becomes accidentally reversed in the dilator it may be restored to its correct position by pumping the dilator partly full of water and then turning the instrument into a horizontal position and rocking it in an up-and-down fashion

e. Each instrument is provided with an orifice stop which can be inserted under water thus making it possible to move from position to position without repriming

f. A sliding scale and foot plate, provided in certain types of instrument, make it possible to clamp the recording orifices at any height above the level of the foot plate This scale and foot plate can be removed in case they interfere with some special use of the instrument.

g. For work in the field, a substantial case for this instrument is necessary to protect it against accidents in transportation.

MECHANICAL CURRENT METERS

Various kinds of mechanical current meters have been devised One of the best known and most dependable is the Price pattern meter the principal feature of which is a bucket wheel rotating on a vertical axis, the rotations of which are transmitted to a recording device Fig 42 represents one of the superior types In this instrument the carefully balanced bucket wheel is mounted on a pivot providing minimal friction The vertical wheel shaft extends into the superimposed enclosed contact box where the rotations of the shaft are transmitted through a set of simple gears to a make-and-break mechanism connected to two exposed binding posts The meter yoke is attached to a guide vane which, when the instrument is in use, keeps the bucket wheel headed into the current. The bucket wheel

assembly and its attached guide vane are carried either on a cable suspension or on a wading rod suspension The instrument may be fastened to the lower end of the wading rod (see Fig 42), or it may be attached to a rod adapter which can be adjusted to any height along the rod In the latter instance, the wading rod has a foot plate at its lower end. These suspensions are interchangeable When cable suspension is employed a 15-lb streamline weight attached immediately below the meter gives added stability of position. A set of flexible, insulated wires, a dry-cell battery, and an earphone with flexible headband complete the outfit.

When the instrument is completely assembled and in position in a stream, the flowing water causes the bucket wheel to rotate. If the upper binding post of the contact box is connected in the electrical circuit, each rotation of the bucket wheel will be transmitted to the earphone as one click, if attached to the lower binding post a click occurs in the earphone for every five revolutions The latter arrangement is used for the higher velocities. The speed of revolution of the bucket wheel is a measure of water velocity Manufacturers provide a rating table which converts the revolutions per unit of time into velocity of flow Such instruments have a velocity range of 0 1–6 5 ft per sec They measure velocity over a period of time, not at a particular instant The operator must have a timepiece, preferably a stop watch, as a part of the equipment since the time interval

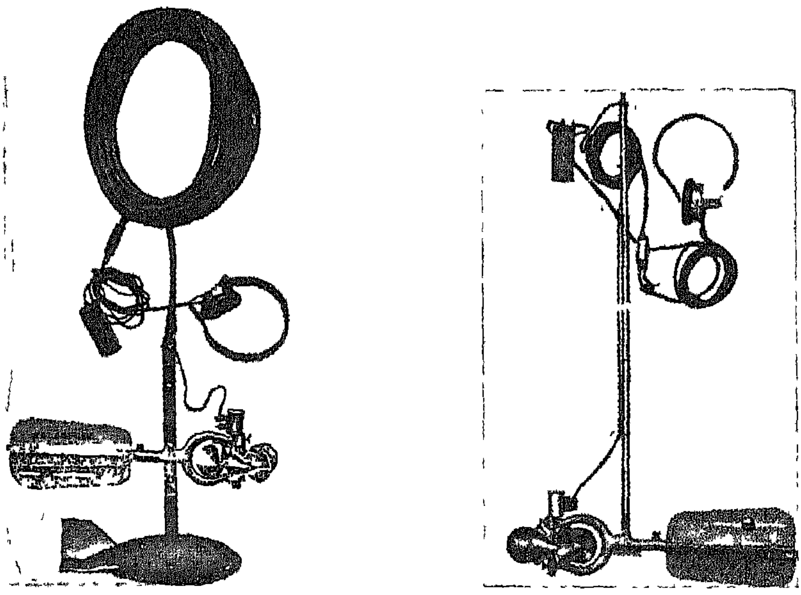


FIG 42 Mechanical current meter, Price pattern (*Left*) Cable-suspension outfit (*Right*) Rod-suspension outfit (Courtesy, W and L E Gurley, Troy, N. Y.)

of each observation must be known The operator may count clicks and watch the time interval simultaneously, or if his funds permit, he may use an electric counter which registers the number of clicks

This instrument has the following advantages (a) Cable suspension permits measurements in deep water, wading-rod suspension facilitates measurements in shallow waters, (b) worn or damaged parts are easily replaceable by the operator, (c) rating of the instrument is not altered by disassembling it

Certain disadvantages are inherent in the instrument (a) Initial cost is considerable, (b) preparation for operation is slow, (c) wires and headphone offer some inconvenience, (d) it cannot be used very close to the bottom or in very small space; (e) it does not measure velocity at any one instant, and (f) it cannot be used among floating vegetation or debris

This instrument, though sturdy in most respects, requires careful treatment in the field, in transportation, and in storage

EKMAN CURRENT METER

The Ekman current meter is commonly used in oceanographic work but limnologists may also have need for such a device in the very large inland waters such as the Great Lakes This instrument records simultaneously both current rate and direction of current The reader is referred to other works for a full description of this instrument, but the essential features are as follows (a) a mounting in ball bearings on a vertical axis, (b) a carefully balanced propeller the revolutions of which are recorded on a set of dials and are a measure of current rate, (c) a compass box and an associated device for recording direction of current, (d) a vane which faces the propeller into the current, and (e) various accessories for starting and stopping the recording of the instrument, for maintaining its vertical balance in the water, and for suspending the meter at the proper level.

THRUPP METHOD

The Thrupp method makes use of the fact that if the surface of a smooth-flowing stream is cut by a small vertical object a definite set of ripples is formed provided the stream velocity exceeds a certain threshold. The angle of divergence of the ripples formed is related to the velocity of the water. Thrupp utilized this relation by devising an arrangement which employs two duplicate obstructions so located that they produce intersecting ripples A Thrupp apparatus can be made as follows Select a straight, flat bar (Fig 43, *ss′*) about 1 m. long and graduate it in millimeters, at its zero end attach firmly at right angles another flat bar *bb′* of similar cross section and about 25 cm long, the top surface of both bars being on same level Attach two pegs (nails with 3 mm. diameter are suit-

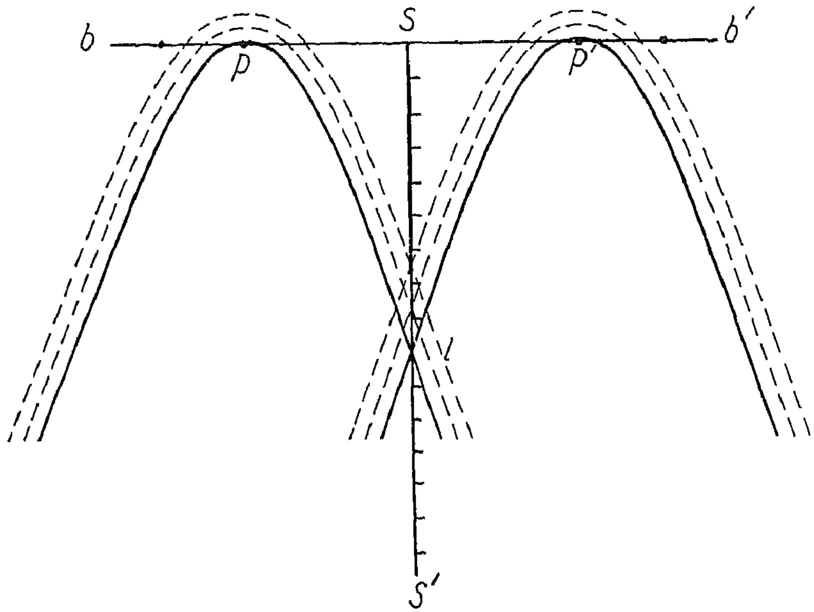


FIG 43 Diagram showing essentials of Thrupp method. (bb') Transverse bar (p, p') Two vertical pegs which cause surface ripples in water (pp') Distance between pegs (ss') Scale (s) Mid-point between b and b' (sl) Distance from s to intersection of inner ripple of one set with that of the other set

able) to the crossbar pp' on exactly the same transverse level of, and equidistant from, the zero end s of the longer bar. Make the pegs adjustable to different distances apart, convenient distances being 10 and 15 cm respectively This apparatus may be made wholly of metal, preferably brass, but if metal supplies are lacking, a crossbar properly fastened to the zero end of an ordinary meter stick serves well, particularly if the whole device can be so loaded that the flotation tendency of wood in water is overcome

In order to operate, hold apparatus in flowing water, peg end upstream, the supporting bars parallel to the water surface and barely but completely submerged. Hold instrument as steady as possible and note point on submerged graduated bar at which innermost ripple from one peg intersects the corresponding one from the other peg and measure distance sl This datum substituted in the following formula will give surface velocity in *meters per second*.

When distance pp' is 10 cm, $v = 0\ 1555l$
When distance pp' is 15 cm., $v = 0\ 1466l$
in which v = velocity in meters per second
l = distance sl in centimeters

General Considerations

a Obviously this method is limited to measurements of surface velocity

b Accuracy of results depends much upon care in using the instrument Even when all personal error is reduced to a minimum, this method is not as satisfactory as those described previously

c. Turbulent surface flowage renders this method difficult or impossible to use.

d This method is not adapted to the measurement of very low velocity.

FLOAT METHODS

In the absence of more satisfactory methods, velocities of the uppermost stratum of water may be measured roughly by means of floats set adrift in the current and the velocity of flow determined by the time required to drift them a known distance. Such floats may be of various materials, forms, and sizes It is important that they be loaded so that they are almost entirely submerged thus reducing the effect of wind action Even so simple a thing as a flat cork with a stone of appropriate size and weight tied to its lower surface will serve in an emergency Various disadvantages are inherent in this method most of which are too obvious to justify mention. Wind, surface disturbances, and eddies are always possible sources of error.

Surface Floats. These floats indicate roughly the surface speed of the stream at the place of measurement only. If such a float passes along the region of highest velocity of water flow, the *mean velocity* of the whole stream at that section may be calculated as 0 8 of the float value It must be understood, however, that such a calculation is only a very rough approximation, since mean velocity is affected by various factors such as nature of bed, size of channel, and amount of discharge per unit of time. The coefficient for transforming observed surface velocity into mean velocity will be highest numerically for large deep streams with smooth, uniform channels and smallest numerically for small streams with irregular, rough beds.

Tube or Rod Floats. A float which gives a different type of information from that of the surface float may be made by selecting a wooden or metal tube of uniform diameter and so weighting it at its lower end that it will float in a vertical position with only a very small portion of its length above the surface of the water Tubes may be loaded properly by pouring lead shot or sand into the lower ends and closing the top A small flag installed in the upper end aids in making the float more visible when used in the water Wooden rods may be used instead of tubes provided that they

are properly loaded at their lower ends Such tubes or rods may be made with adjustable lengths if desired The length of such floats must be determined by the user in adapting them to his needs If it is the purpose of the operator to secure a direct measurement of the mean velocity of the water in that particular vertical plane in which the rod moves, then the rod should be made as long as free flotation will permit, that is, the clearance between the lower end of the float and the objects on the bottom should be as small as practicable However, any dragging of the lower end on the bottom will invalidate the results Data resulting from rod- or tube-float measurements should always be accompanied by information as to the length of the float, the mean depth of the stream, and the position of the plane of flotation Obviously rod or tube floats are not suitable for streams in which submerged vegetation or other kinds of obstructions are prevalent.

When a rod float is released in a stream, the velocity of its movement will be approximately that of the vertical thin stratum or "filament" of water in which it drifts Hence, the velocity of filaments in different positions in the cross section of the stream can be measured If the immersed length of the rod is about 0 9 of the total depth of the stream, then, according to some authorities, the mean velocity of the filament of water in which it drifts may be calculated by means of the following formula·

$$V_m = V_r \left[1 - 0\ 116 \left(\sqrt{D} - 0\ 1\right)\right]$$

in which

V_m = mean velocity of water filament
V_r = observed velocity of rod float
D = ratio of depth of water below bottom of rod to total depth of water

The mean velocity at any cross section of the stream may be determined by introducing the float several times at different positions and observing the velocities

In the operation of rod floats definite arrangements must be set up for determining the *time* and *course* of each float Where applied to small streams, a wire or rope graduated with tags may be stretched across the stream at each end of the section of stream to be measured, the rod float released above the upstream line, the time required for the float to pass from one line to the other noted, and the length of the course of the float determined In a large stream, some other arrangement will be required, as for example, the following one Establish two ranges, one at each end of the section of stream to be measured, and at right angles to it, determine distance between ranges, set up a transit on each range, set transits to read zero on each other, start rod float just above upstream range, transitman on upstream range signals transitman on downstream range (a) when

float is *about* to cross range and (b) when it *does* cross range, downstream transitman reads an angle on float just as it crosses upstream range, repeat this procedure when float crosses downstream range, the upstream transitman reading angle on float, each transitman records time of crossing range at which he is located. This procedure makes it possible to determine (a) *course* of the float, and (b) *time* required for float to drift from one range to the other. These operations may be repeated either at the same position along the range or at different positions and the results recorded In the latter instance, results are secured which make possible the construction of a cross-section diagram of the stream at the position of the downstream range with velocities of the various filaments of water indicated

Volume of Flow of Streams

In nature, surface streams running in nonartificial, open channels ordinarily present so many departures from a uniform condition that the formulas of the hydraulic engineer for open-channel computations cannot be applied with any dependable accuracy If the character of the data desired and the features of the stream are such that the installation of weirs is justified, then the volume of flow can be measured with considerable accuracy and the mathematical formulas appropriate for weir computations may be found in almost any treatise on hydraulics. Commonly, however, the limnologist is forced to be content with less accurate results secured by means of simpler approaches. Embody's formula (1927) is expressed as follows

$$r = \frac{wdal}{t}$$

in which

r = rate of flow in cubic feet per second
w = average width of channel section tested
d = average depth in feet
a = constant
l = length in feet of channel section tested
t = average time (three tests) in seconds required for float to traverse channel section

In this formula it is assumed that rate of flow is measured by timing the passage of a float over the selected channel section If a current-meter reading in feet per second is available and the average velocity over the selected channel section is determined, then the formula becomes

$$r = wdav$$

in which v = average velocity of water over section tested The value of a depends upon the nature of the bottom. If the bottom is rough and com-

posed of loose rocks and coarse gravel, *a* has a value of 0.8; if smooth and composed of such materials as mud, sand, hardpan, or bedrock, *a* is given a value of 0.9.

Current velocity measured by timing a float in mid-current is upper-stratum velocity only. In the absence of current meters, a somewhat more accurate value for current velocity can be obtained as follows: if the channel is not more than 2 ft. deep, multiply the surface current rate by 1.33; if 10 ft. or more in depth, multiply the surface current rate by 1.05; for intermediate depths, interpolate between these two values.

Average depth is computed by measuring the depth of the water at uniform horizontal intervals across the stream and dividing the sum of such depths by the number of intervals plus 1.

GENERAL CONSIDERATIONS

a. Streams having a volume flow of less than 1 cu. ft. per sec. are sometimes described in terms of gal. per min.; 1 cu. ft. per sec. is approximately equivalent to 450 gal. per min.

b. Records of volume of flowage should be accompanied by information concerning the water level, since high or low water conditions alter the flowage markedly.

c. It must be remembered that any values secured by means of Embody's formula are approximate only.

STREAM DISCHARGE FROM ROD-FLOAT DATA

From results secured by the rod-float method described on pp. 151–153, it is possible to calculate approximately the stream *discharge* by multiplying the mean velocity of each water filament by its cross-sectional area and adding the products so secured. Improved results are obtained if two or more sections within the entire stretch between ranges are measured in order to compute a mean section.

Direction of Water Currents

SCOTT'S VANE METHOD

Direction of water currents, particularly in shallower water of the littoral region, may be determined by the use of an instrument modified from Scott's (1916) vane method. This modification consists of a galvanized iron vane 75 cm. long and 25 cm. wide mounted vertically in the end of a graduated steel rod 2 m. long and counterbalanced in such a way that it hangs vertically when suspended in water. The upper end of the rod is attached to the axle of a front-wheel bicycle hub which serves as a handle and allows the suspended vane to swing freely on the ball-bearing support. On the upper end of the axle a small pointer is fastened thus pro-

viding means of determining current direction when the vane itself is not clearly visible

Ordinarily, this instrument can operate only in very shallow water By the use of sectional extension rods, Scott found it possible to use his instrument to depths of 30 ft or more with satisfactory results

STREAMER METHOD

A simple method of studying current direction in shallow water may be devised as follows· A rod of convenient dimensions is installed in a vertical position at the desired location by thrusting it into the bottom. At regular intervals along the submerged portion of the rod, pieces of red silk ribbon or silk thread are tied at one end, leaving the other end free Currents may be detected and their direction determined by watching the behavior of the ribbons at the various levels above the bottom. Obviously, this method is not usable in very turbid water Its use in clear but rough water may be facilitated by the aid of a water telescope (pp. 363–364)

Detection and Measurement of Seiches

Methods for the measurement of ordinary changes of water level have been described on pp 61–64 Such methods may be adapted also to the detection and measurement of seiches if general information only is desired For a highly precise and detailed study of seiches, various complicated and costly types of recording equipment have been devised, a discussion of which falls outside the province of this book For information concerning these refined instruments the reader must consult some of the more extensive research papers dealing with investigation of seiches However, certain simpler outfits yield general information and, while their limitations must be fully understood, results so secured may be useful for some purposes.

INDEX LIMNOGRAPH

An example of simple equipment is represented in Fig 44 It is a modification of a device, known as an *index limnograph,* first employed by European workers many years ago. It consists essentially of a very sturdy tripod, an immobilized small table *t* with a vertical back piece *vb* of similar size attached to it at one edge, a float *f* from which a flexible, inelastic cord *c* passes vertically over a pulley installed on the table, and vertically downward to a counterpoise, and an index or pointer, attached to the pulley *p,* which operates over a graduated scale *s* on the vertical back This outfit is mounted over an improvised still well *w* at the margin of the lake. The graduated scale may have any form and pattern which convenience dictates

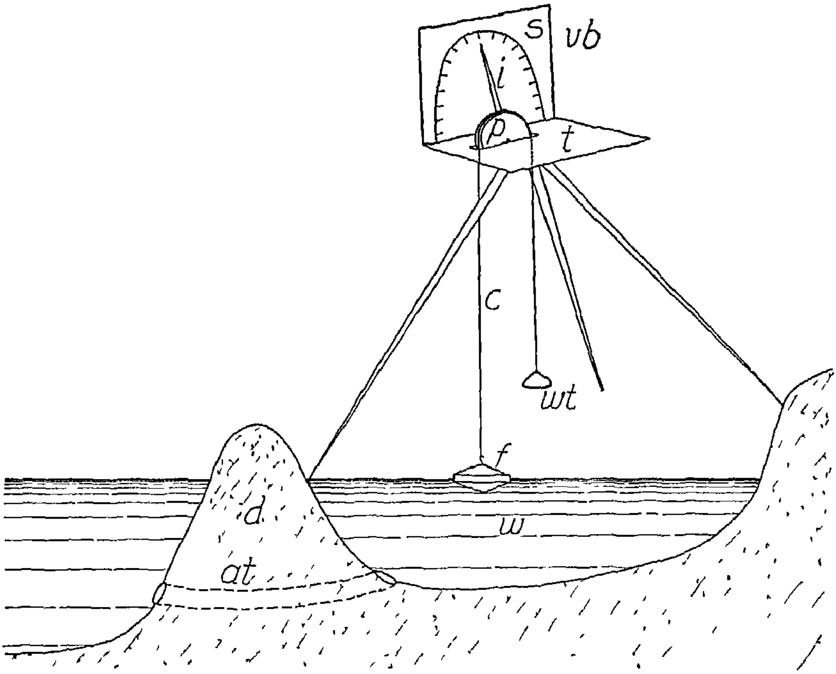


Fig. 44 Diagram of essential features of a simple index limnograph (*at*) Subterranean access tube connecting lake with improvised still well (*c*) Cord passing from float, over pulley, to counterpoise (*d*) Dam separating still well from lake (*f*) Float (*i*) Index or pointer fastened to back surface of pulley (*p*) Grooved pulley mounted in table over which passes cord connecting float and counterpoise (*s*) Scale mounted on vertical back piece (*t*) Horizontal table (*vb*) Vertical back piece (*w*) Improvised still well (*wt*) Counterpoise

Procedure

1 Set up limnograph in laboratory and calibrate graduated scale by raising and lowering float known distances

2 Adjust weight of counterpoise to provide for proper performance of float.

3 In field, select suitable position at lake margin, construct improvised still well as indicated in Fig 44, excavating basin to such depth that all possible changes of water level are provided for. Install access tube *at* to connect still-well basin and lake basin

4. Set limnograph over still well and make as stable as possible Adjust pulley position so that all changes of position of float will register on vertical scale.

5 Make records of index position at regular intervals of time so chosen that the size of the time interval is appropriate to the demands of the work

General Considerations

a This method requires that the limnograph be under constant observation during the period of work since usually the time interval for recording must be short

b If desired, records may be plotted as they are taken by the use of cross-section paper mounted on a board of convenient size. By plotting *time* along the abscissa and the index values along the ordinate a curve can be constructed as the work progresses.

c. Adequate protection against rain and windstorms must be provided

EQUIPMENT FOR CONTINUOUS RECORDS

In the study of seiches it is often desirable to have a continuous record extending over several hours and possibly during times when the instruments cannot be under constant observation Elaborate and costly instruments, designed especially for this purpose, fulfill such requirements, but since they are not discussed here it should be mentioned that certain simpler devices may yield continuous records satisfactory for some purposes An example of such a simpler instrument is that sometimes designated as the *wagon recorder* Changes in water level are transmitted by a float, line and counterpoise, similar to those of the index limnograph, but the line passes over two pulleys between which it drags, back and forth, a little carriage carefully mounted on three wheels that run, one on one side and two on the other, on two parallel tracks This carriage supports a stylographic pen or pencil, so located and controlled that its movements are recorded on a long strip of paper moved horizontally and perpendicularly to the movement of the pen or pencil on rollers operated by a clockwork mechanism Thus the rise and fall of the water surface is recorded on the paper, in a continuous record. Such an apparatus is easily constructed at modest cost in any laboratory from materials readily obtainable Obviously, the best records are provided when it is operated in connection with some form of still well The apparatus is easily calibrated in the laboratory

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LIGHT PENETRATION

Methods for the measurement of light penetration in water fall into two general groups, namely, limit of visibility tests, and light measurements

Limit of Visibility Methods

SECCHI DISK

Secchi disk, as now used, is a circular metal plate, 20 cm in diameter, the upper surface of which is divided into four equal quadrants (Fig 45) and so painted that two quadrants directly opposite each other are black and the intervening ones white. A staple fixed at the center of the upper surface provides attachment for the graduated rope Opposite the staple on the lower surface is a weight which facilitates the sinking of the disk in proper position. The lower side of the disk is painted black in order to eliminate reflection of light from that surface. Use of Secchi disk consists in lowering it into the water on a graduated line, noting the depth at which it disappears, then lifting the disk and noting the depth at which it reappears. The average of these two readings is considered to be the *limit of visibility*. For more exact results the disk, as it sinks, should be viewed vertically through a water telescope and under a sunshade

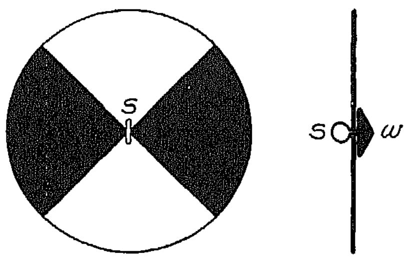


Fig 45. Diagrams showing construction of Secchi disk (*Left*) View of upper surface showing alternate black and white quadrants. (*Right*) Transverse section through center (*s*) Staple at center (*w*) Weight at center on lower surface.

This method has come into wide use as a routine means of comparing different waters Obviously it is not an actual measure of light penetration, but merely a useful, rough index of visibility. It is also useful in making comparisons of the same water at different times. Readings made at the same date on the same water will vary with different observers, with the time of day, with the degree of roughness of water, and with the clearness of the atmosphere Therefore all Secchi-disk records should carry full information on these items.

Standard conditions for the use of the Secchi disk are as follows clear sky, sun directly overhead, shaded, protected side of boat, under a sunshade, minimal waves or ripples (or use water telescope). Any necessary departure from these conditions should be specifically stated in the records

General Considerations

a. The upper surface of the disk must not be allowed to become dull or scarred. Frequent painting or enameling is recommended

b If the water is rough the protected side of the boat must be used

c If a water telescope is not available, the observation should be made on the shaded, protected side of the boat with the observer's eye at some fixed distance above the surface of the water. When small boats are used, a distance of 1 m is suitable.

d Observations should be made during the middle of the day, early morning and late afternoon hours must be avoided

e. The rope must be accurately graduated and the graduations made as fine as practicability will permit A steel tape is an excellent substitute for a rope but may rust unless it is kept dry when not in use

f An incandescent light, substituted for a Secchi disk, is more complicated, cumbersome and not justified in ordinary practice Such equipment is subject to the same limitations as the Secchi disk and has no essential advantages.

g A Secchi disk may be made up with a suspension composed of three cords attached to the edge of the metal disk, equidistant from each other, and converging upward to union with the graduated line, also on the opposite surface a similar suspension may be provided for the weight Such suspensions hold the disk more steadily in a horizontal position when it is sinking, but the uppermost suspension interferes with visibility and the lower one may become entangled with objects on or near the bottom. The disk as described in this section avoids both disadvantages.

Light-measurement Methods

Satisfactory methods for the qualitative and quantitative measurement of light in water are developments of very recent years Improvement and reduction in cost of the photoelectric cell are the outstanding events in the history of such methods At the present time, rectifier cells of the selenium type appear to be the most satisfactory means for measuring subsurface daylight Improvements in photoelectric cells and the accessories necessary for subsurface measurements are constantly appearing and some of the present devices for securing high-precision results are complicated, highly technical, and exacting in time and experience So rapidly is the picture changing that no attempt will be made here to do more than indicate the

general features of an outfit which, at the present time, is considered suitable for routine limnological work

PHOTRONIC CELL OUTFIT

Assembled outfits for measurement of subsurface illumination are not yet available on the market Hence each worker must arrange individually for the construction of his equipment He must understand the essential details of the device and will probably require the assistance of some physicist familiar with photoelectric cells and their uses This account follows the recommendations of the Subcommittee on Light Measurements of the International Council for the Exploration of the Sea (Atkins, Clarke, Pettersson, Poole, Utterback and Ångstrom, 1938) Only essential features are discussed here Construction and assembling details are omitted since they may vary widely with different types of materials, and with various uses which the outfit is to serve

PHOTOMETERS Photronic cells manufactured by the Weston Electrical Instrument Corporation have been found suitable and reliable when operated under proper conditions Two such cells, properly mounted, are needed, one to be used as the *deck instrument* and the other as the *subsurface photometer*

The deck photometer requires no special mounting unless it is expected that the instrument must be exposed at times to rain or spray Ordinarily it may be mounted in any convenient type of container so constructed that the instrument window is horizontal and that the necessary glass plates and color filters may be properly installed A gimbaled support is advantageous although not necessary

The subsurface photometer requires special mounting It must be installed in a case which is absolutely watertight under all conditions of use The case must be compact, sturdy, much heavier than an equivalent volume of water, and capable of suspension with the cell window horizontal It must also be so constructed that the opal-glass disk and color filters, to be mentioned later, can be installed or removed quickly, also so built that the upper rim of the case does not produce any appreciable shading of the low-angle light Other details are described in the reference already mentioned (Atkins, *et al.*, 1938) Particular attention should be given to the method of union of the cable to the photometer The case should be provided with a supporting bridle by means of which the photometer in its heavy case can be attached to the galvanized supporting rope. This bridle should be composed of two strands of strong, small-diameter galvanized steel cable, long enough to produce a minimum of shading on the photometer

MICROAMMETERS Two suitable, duplicate microammeters are required (see p 167 for possible use of but one microammeter), one to measure the

current from the deck photometer and the other to measure current from the subsurface one. The choice of an instrument for the measurement of these currents involves a number of considerations and the decision must be determined by such things as the nature of the proposed measurements, degree of precision, cost, and adaptability It is probable that, at this point also, most limnologists should seek the advice of a competent physicist For routine purposes where high sensitivity is not expected, certain microammeters which serve the purposes are now obtainable at relatively low cost. However, highly sensitive microammeters are required for very precise work

Diffusing Glass Since a photronic cell mounted beneath a clear glass window will not give an accurate measure of light falling on a freely exposed horizontal surface because of the fact that the rim of the case interferes with reception of low-angle light, it is necessary to reduce this error by use of a *diffusing glass* This diffusing device is in the form of a disk of flashed opal glass mounted above the photronic cell and in contact with the water If this glass meets certain specifications, it combines desirable diffusing action with minimum loss of light. Both surfaces of the glass are polished and the diffusing layer is internal thus avoiding any interference with the diffusing action by submersion in water When used, this diffusion disk is always the outermost part of the window structure Both deck and subsurface photometers must be supplied with diffusing disks

Color Filters Selenium rectifier cells have a sensitivity over the visible spectrum and beyond it at both ends, have maximum sensitivity at about 5900–6000 Å., and have rapidly declining sensitivity toward both ends of the spectrum (drops off to 10 per cent of maximum at about 7000 Å. and at about 3400 Å) For well established reasons which need not be reviewed here, it is usually advisable to limit the range of sensitivity by the use of color filters of which the following are likely to be most useful for routine purposes (a) If but one set of measurements is to be made, a Schott green filter VG9 (maximum sensitivity near 5400 Å , range about 4800–6000 Å) will probably be most suitable, (b) if other readings are to be made, a Schott red filter RG1 (transmits freely above sharp cutoff at 6000 Å , upper limit determined by falling sensitivity of cell and for daylight is about 7200 Å), and a Schott blue filter BG12 (maximum sensitivity near 4300 Å , range about 3600–4800 Å under diffusing glass and thick glass window) are recommended

Accessory Equipment Galvanized strand steel rope of least diameter which will provide necessary tensile strength is recommended It should be graduated in convenient units, if not used in connection with a recording meter block, and used on some form of winch or hoist The lifting device should be of such construction and occupy such a position that a minimum of shading is produced

This cable must have a certain margin of excess length over the maximum depth of the water in which it is to be used. If it is to have a length of more than a few meters it should be used on a drum

The connections between the deck photometer and its microammeter should be of convenient length, well insulated, equipped with adequate terminals, and have a resistance as nearly as possible that of the connecting cable for the subsurface photometer in order that the two sets of instruments will yield very similar readings when under the same light exposure.

Since the subsurface photometer is housed in a heavy brass case, additional weight may not be necessary to insure prompt sinking and maintenance of vertical position of the supporting steel rope. However, in case of doubt, a sinker weight of elongated streamline shape and equipped with a tail fin should be suspended from the lower part of the photometer case, care being taken not to interfere with the horizontal position of the photometer window Such a sinker arrangement is also useful in preventing rotation of the photometer and twisting of cables when it is being hoisted on board the boat.

STANDARDIZATION OF PHOTRONIC CELLS. Measurement of subsurface illumination may be expressed in two general ways (a) percentage of surface illumination, and (b) definite units.

PERCENTAGE OF SURFACE ILLUMINATION. For many kinds of work adequate results are secured if the subsurface illumination is expressed as a percentage of the surface illumination in the same spectral band. From such results it is possible to determine the relative penetration of the light of one kind of color in the water concerned. In this simpler method, it is only necessary to know the relative sensitivity of the deck and subsurface photometers and the curvature corrections of each. Current generated by photronic cells is not exactly proportional to the illumination producing it but departs from a linear relationship The greater the illumination the greater the curvature from the linear, also the greater the external resistance the greater the curvature relation Therefore, it is clear that such cells, their cables and microammeters must be standardized against some standard light source and the proper curves drawn from values determined for different illuminations If a microammeter having a series of different resistances is used, then each resistance scale must be standardized. The different glass color filters must be standardized in the same fashion

DEFINITE UNITS. For some purposes it may be necessary to express light-penetration results in terms of definite units At this point it is probable that the limnologist should engage the assistance of a competent physicist. It has been suggested by certain authorities that it may be desirable to express these units in terms of radiant power, such as milliwatts per square centimeter, or gram-calories per minute per square centimeter in the particular spectral bands concerned. For the present at least and

until certain problems relating to the standardization of color filters are solved, the Subcommittee on Light Measurements of the International Council for the Exploration of the Sea makes the following recommendations

1. Employment of some definite although arbitrary unit to measure the illumination as shown by the photometer with and without various color filters

2 Unit may be called the *lux* when the photometer is used with plain opal diffusing glass but without color filters

3 Readings of photometer with the opal glass and color filters used simultaneously may be expressed in red units, green units, blue units, etc , respectively.

4 One *red* unit in this system would be defined as representing the red light (6000–7200 Å) in a total illumination of one lux as supplied by a standard source Other color units (green unit, blue unit, etc) are defined in a similar way.

5. In the choice of a standard source the following requirements should be observed (a) If standardization is expressed in visual units, the spectral composition of the standard source should closely resemble that of average daylight, if expressed in radiant power units the color temperatures must be accurately known, (b) the standard source should provide an intensity of illumination corresponding to that to be measured by the photometer, thereby reducing the curvature correction which must be determined for the whole range of use

6 The standard filament lamp, the artificial mean noon sunlight secured with such a lamp equipped with the Davis-Gibson double liquid filter, and the carbon arc are suggested as standard sources. The second is regarded as the most satisfactory for standardizing selenium cells in visual units.

PROCEDURES FOR MAKING MEASUREMENTS

1. On open, level, unshaded portion of deck, set up instruments, making proper connections between one microammeter and deck cell and between other microammeter and cable leading to subsurface cell

2 If "lux" measurements only are to be made (a) install plain opal diffusing glass in place over deck cell, (b) similarly, install opal glass over subsurface cell, *completely filling space between window and opal glass with water*

3. If measurements are to be made in terms of color (a) install selected color filter over window of deck cell and superimpose opal diffusing glass, (b) similarly, install selected color filter over window of subsurface cell and superimpose opal diffusing glass, *completely filling the spaces between window, color filter, and opal glass with water*

4 With both cells under same conditions of illumination, make readings on both microammeters and compare results Interchange microammeters to determine if reading is essentially the same—a condition which should prevail if the two microammeters are duplicates and if the cells are in good condition A constant difference in reading of the two duplicate microammeters indicates difference in resistance in the two systems and such difference must be taken into account in interpretation of results If desired, the two systems may be equalized by installation of a suitable shunt

5 When preliminary arrangements are being made under unobscured sunlight, a reading of diffuse light by screening off direct sun by holding small opaque object between sun and cell at distance of about 2 m from latter should be made A convenient index of relative intensity of sunlight is provided by ratio of total to diffuse light It is usually recommended that this measurement be made at the beginning and the end of each vertical series

6 When all preliminary preparations and records are completed, lower subsurface cell to first desired depth, observing following precautions (a) Be sure subsurface cell is free from direct shadows created by boat, (b) make certain that subsurface cell is so suspended that its window is horizontal, and (c) if possible, insure that supporting line is vertical in position, if this is not possible, then note approximately that angle from vertical made by supporting line.

7. Make simultaneous readings of two microammeters and record results Also record time and other circumstances which bear upon problem of light penetration at that moment.

8. Lower subsurface cell to next selected depth and repeat readings and records Continue until whole vertical series is completed Make series as rapidly as possible in order to minimize possible changes in light or in water. If changes are occurring due to shifting light at surface, to effects of water flowage, or to other circumstances, the series may be repeated in reverse order as subsurface cell is brought to top and results of two readings at each level averaged, or results treated in any other desirable way.

9 At conclusion of each series, determine ratio of direct to diffuse light at surface as outlined in paragraph 5.

CALCULATION AND RECORDING OF RESULTS

Results secured in ordinary routine work should be entered on some record form such as the one suggested in Form 6 The calculations and the units used will depend upon the kind of work in progress For the simpler information concerning light penetration, both with the opal diffusing glass and some selected color filter, calculation of the per cent of the light transmitted to a selected depth in terms of the total amount

registered by the deck cell may be sufficient Results more detailed than the computation of per cent transmitted will depend upon the proper standardizations and calibrations of both the microammeters and of the phottonic cells and their filters It is likely that at this point the aid of a physicist should be secured, and no attempt will be made to introduce the more elaborate methods here

For the determination of the per cent transmitted, all that is necessary is to translate the two microammeter readings into terms of actual illumination by use of the illumination curves resulting from the standardization of the cells From these transformed values the calculation of the per cent transmitted at the selected depth is simple.

FORM 6

LIGHT PENETRATION RECORD

State	Wind	Boat
County	Sky	Operator
Water	Air Conditions	Recorder
Station	Air Temperature	Apparatus
Date	Surface Illumination Deck Cell	Opal Glass
Time	Subsurface Cell Exposure	Filters
Water Surface		

No	*Depth (m)*	*Temp (C)*	*Deck Cell Reading*	*Subsurface Cell Reading*	*Per Cent Transmitted*	*Remarks*

GENERAL CONSIDERATIONS

a. Photronic cells must be protected against high temperatures When exposed to direct sunlight for any considerable interval, an infrared filter should be used

b. Both deck and subsurface cells must be kept dry at all times. The subsurface cell must be watched with particular care since it is submerged when in use and under rising water pressures as the depth is increased Frequent inspection of the photometer case and of its various packings is imperative.

c. Continuous exposure of Weston cells (type 1) to high illumination does not, *per se*, damage the cells.

d. Measurements of light penetration should be made as near midday as possible.

e. Some investigators have found that, for most purposes, one microammeter provided with a double-throw switch can be substituted for the two instruments described above

Other Methods

An instrument known as a pyrlimnometer was designed by Birge and Juday (1931) and in their hands has yielded much valuable information concerning light penetration in lakes Thus far its use has been almost exclusively confined to the Wisconsin laboratory

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WIND VELOCITY

Many limnological phenomena are related, directly or indirectly, to air movements and wind-velocity data often become a necessity. Far too commonly the limnologist must work in regions remote from weather-bureau stations, astronomical observatories, and other institutions making routine wind measurements, hence he is obliged to provide his own means of securing information. In all situations an accurate, local measure of air movement is obtainable only by an instrument operated at the locations concerned

Anemometers

Anemometers may be classified (Middleton, 1941) into five principal groups on the basis of method of performance, namely, (a) rotation, (b) pressure-plate, (c) bridled, (d) pressure-tube, and (e) cooling Of these, the rotational, pressure-plate, and pressure-tube types are more likely to be used for limnological purposes, although obviously any standard type may be employed if available and practicable for the work in hand Rotation anemometers are commonly of two kinds. (a) the *cup* type with vertical axis, and (b) propeller (windmill) type with horizontal axis and with blades either flat or helicoidal

CUP ANEMOMETER

The well-known cup anemometer is a standard rotational instrument in general meteorological practice and no description is needed here Certain of the simpler forms may be used on temporary installations and supply data useful for some purposes The ideal types are those mounted in elevated situations and equipped with continuous recording mechanism, but such outfits are very expensive and require considerable attention So many types are on the market and so readily available is the detailed information about them that the limnologist will have little difficulty in seeking those best suited to his needs The cup anemometer gives wind velocity over a selected period of time.

PROPELLER OR WINDMILL TYPE

The well-known Biram anemometer (Fig 46) is particularly useful for some limnological purposes It has the advantage of being portable The blades of the propellerlike wheel are usually flat Several dials record the

number of revolutions of the wheel. Calibrations and corrections are commonly supplied by the makers Like the cup anemometer, this instrument gives wind velocity over a selected period of time only A correct record depends upon the operator's facing the instrument into the wind current However, an installation can be improvised by suspending the instrument on a cord, holding it in vertical position by a counterweight suspended beneath, and by attaching a very lightweight vane to the instrument in such a position that it will not interfere with the air flow. This vane will hold the receiving side of the instrument (side opposite the dials) in the face of the wind

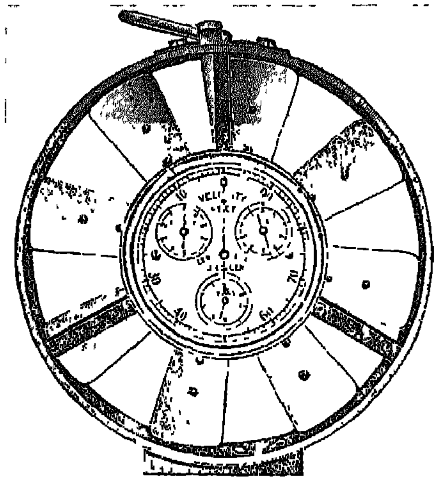


FIG 46 Biram anemometer. (Courtesy of Eugene Dietzgen Co, Chicago, Ill)

PRESSURE-TUBE ANEMOMETER

PITOT TUBE Certain forms of Pitot tube may be adapted to the measurement of air velocities The type described on pp 142–145 may be used for that purpose If it were possible to use air in the manometer when determining wind velocities in the same way as water is used in the manometer when measuring water velocities, the height of the air column would be the value needed in order to compute the air velocity. But since air cannot be so used in the manometer it is necessary to employ water or some other suitable liquid. Some makers supply calibrated Pitot tubes and a set of curves from which the velocity of the air can be ascertained directly when the manometer is read Such curves are made for the particular instrument used, stated conditions of temperature, barometric pressure, humidity, and the kind of liquid used in the manometer Fig. 47 is a dia-

gram illustrating the principal features of a Pitot tube used for measurement of air velocities.

When the air velocity is being measured, particularly the lower velocities, difficulty may be experienced in reading the small level differences in the manometer tubes when the manometer is in a vertical position. This difficulty may be avoided by inclining the manometer to that angle which increases the reading over the normal one by some definite amount For example, if the manometer is inclined 30° from the horizontal the readings are twice the normal value, if inclined at an angle of 5 75° from the horizontal the readings are 10 times the normal value

The pressure difference in a Pitot tube is proportional to the square of the velocity and the following formula indicates the relations

$$P = \frac{9992.24\, a\, C}{gd} V^2$$

in which

P = pressure difference in millimeters of water
a = density of air in grams per cc
d = density of water in grams per cc
g = acceleration in centimeters per sec.^{2} due to gravity
V = air velocity in miles per hour
C = constant

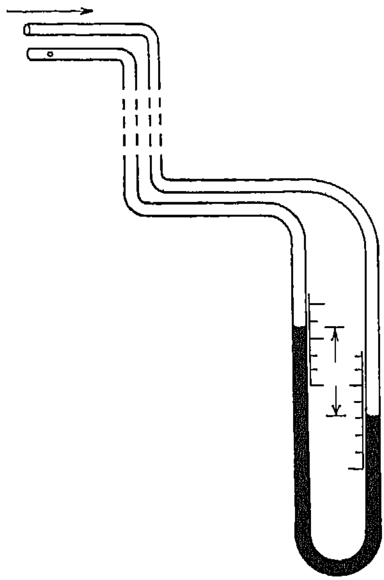


FIG 47. Diagram showing general features of a Pitot tube as used for measuring wind velocity Horizontal arrow indicates direction of air flow Upper, *pressure* tube is open ended; lower, *static* tube is closed at the end but has holes in the side. Vertical arrows indicate difference of level in the two columns which is a measure of wind velocity (Modified from Negretti and Zambra, London, England)

Under ordinary conditions of temperature and pressure the formula is

$$P = 0\ 012504\ V^2$$

A very useful and convenient accessory to the Pitot tube for air-velocity measurements is the differential inclined-tube liquid gage which enables the operator to read velocities directly in conventional units

PRESSURE-PLATE ANEMOMETERS

WINDIKATOR. Various other means for measuring wind velocity have been devised. A simple, inexpensive instrument now on the market and

known as a "Windikator" serves many routine limnological purposes reasonably well. The mechanism consists essentially of a pressure vane delicately geared to a pointer rotating over a graduated dial, the units of which express wind velocity in miles per hour. To operate, the base of the instrument is held at chin level in either hand with the wind velocity dial toward the face of the operator; then the operator turns his body, swinging the windikator in the arc of a circle, until that position is reached in which the wind stream meets the pressure vane to the fullest extent, thus securing the maximum reading on the wind velocity dial. This apparatus is also equipped with a compass and reference lines by means of which wind direction is also determined. It is a serviceable instrument for securing routine information in local situations

WILD'S PLATE

A simple inexpensive means of measuring wind velocity which is known under the name of Wild's plate is a modification of the ancient Hooke's pendulum anemometer. It consists of a sheet-iron plate, 30 × 15 cm. in dimensions, weight 200 g., loosely hinged at one end to a suitable support When set up for use, the support faces into the wind and the plate hangs from one edge in a vertical position. Air movement exerts pressure against the surface of the plate and lifts it, the amount of lifting being a measure of wind velocity Some convenient means of measuring the angle between the plate and the perpendicular when influenced by the wind is provided. This device should be mounted on a wind vane in order that it may automatically adjust to the varying direction of the wind and insure that the plate faces the direction of maximum air-mass movement. It must be understood that Wild's plate, under the best of conditions of mounting and operation, will yield results of only approximate accuracy. Obviously such a device must be calibrated against some standard in order to make its results usable. According to Landsberg (1941), Wild's plate with dimensions and weight mentioned above will have wind velocity relations as indicated in Table 13, Appendix.

MAXIM PRESSURE-PLATE ANEMOMETER

Another pressure-plate anemometer of simple construction is illustrated in Fig. 48 The pressure plate against which the wind blows is 13 in. in diameter and wind pressure is transmitted directly to an index operating over a graduated scale Wind velocity is read directly in miles per hour.

WIND VELOCITY ESTIMATIONS

Long ago, the need for some means of estimating and describing various wind velocities gave rise to numerous proposals known as *wind scales*, prominent among which was the well-known Beaufort twelve-point scale.

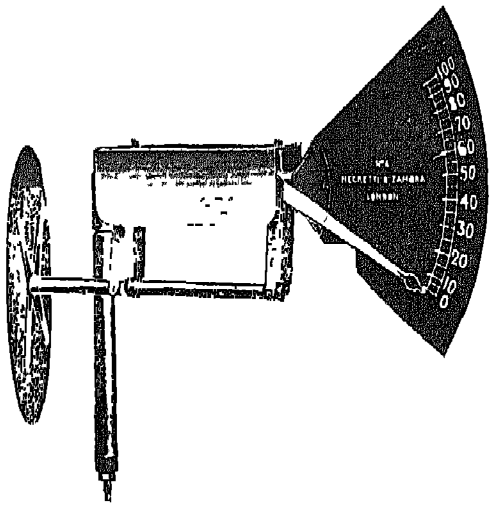


FIG 48 Maxim pressure-plate anemometer (Courtesy, Negretti and Zambra, London, England.)

The later development of instruments for measuring air movements caused these wind scales to be largely superseded However, for certain descriptive, routine, and substitutional purposes a scale, such as the Beaufort scale, may be of some value to the limnologist (see p 355) In almost any standard treatise on meteorology will be found a discussion of the Beaufort and other scales.

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BOTTOM MATERIALS

Bottom Samplers

The requirements of bottom sampling are so diverse that no one sampler has been devised which will serve all purposes. For preliminary or reconnaissance work certain simple forms of sampler may be used in most situations, but for more precise work they must be chosen in accordance with the particular needs of the program and the structure of the bottom materials

EXPLORATORY SAMPLERS

A combination sounding weight and bottom sampler, illustrated in Fig. 8 is a useful exploratory instrument One serviceable type weighs about 5 lb. The conical cup at the lower end acts as a bottom sampler As it descends to the bottom the water pressure holds the cover *v*, composed of two layers of sole leather, above the edge of the cup On reaching the bottom the cup sinks into the deposit and fills, then when drawn upward the water pressure acts in the other direction pressing the cover down upon the top of the cup and keeping it closed until arrival at the surface If the sampler is in good condition a sample so taken is delivered at the surface with no significant loss or mixing In soft bottoms such a sampler sinks for a certain distance into the deposit, usually securing a sample below the uppermost surface of the mud.

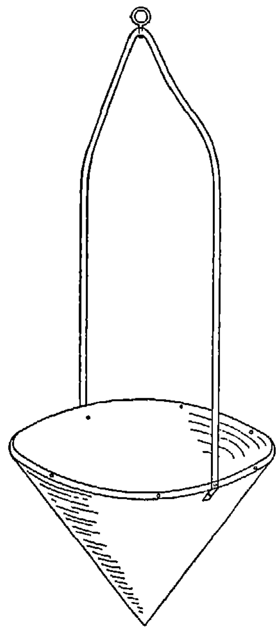


Fig 49. Scoop sampler designed for U S. Public Health Service.

A simple scoop sampler, designed for the U.S. Public Health Service, is illustrated in Fig 49 It consists of a cone-shaped cup fastened to a strap-iron handle The rim of the cup bears a cutting edge In operation, a rope is attached to the free end of the handle and the sampler thrown into the water It is dragged along the bottom for a selected distance, then brought to the surface The cup may be of any convenient size. Obviously, such a sampler must be used in shallow water, and it secures a sample suitable for general purposes only

EKMAN DREDGE

Of all the various bottom samplers, the Ekman dredge is so preeminently successful and so widely used for soft bottoms that it has become the standard instrument. In its present form (Fig. 50) it is modified from the original Ekman design by being adapted to the use of a messenger for closing. It is commonly built in two sizes, one having a cross section of 6 × 6 in. (15.2 × 15.2 cm.) and the other 9 × 9 in. (22.8 × 22.8 cm.). The body of the dredge consists of a square or rectangular box of sheet brass. The lower opening of this box is closed by a pair of strong brass jaws so made and installed that they oppose each other and, when shut, close tightly; when fully pulled apart, they leave the whole bottom of the box open. Two strong external springs, when released by the messenger,

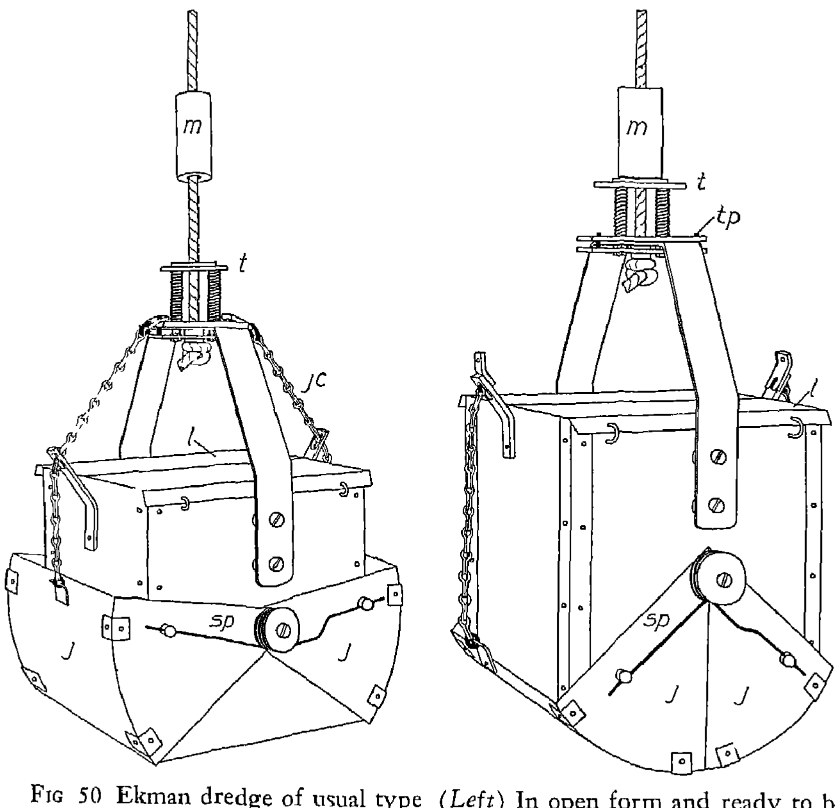


Fig. 50. Ekman dredge of usual type. (*Left*) In open form and ready to be lowered into water. (*Right*) In closed form after messenger has released trip mechanism and jaws have closed. (*j*) Jaw. (*jc*) Jaw chain. (*l*) Top lid. (*m*) Messenger. (*sp*) Spring which operates jaws. (*t*) Trip mechanism. (*tp*) Trip pin.

snap the jaws shut. The top of the box is closed by two thin, hinged, overlapping lids which open easily when the dredge is descending through the water but which close and are held tightly shut by the water pressure while the dredge is lifted to the surface A spring mechanism at the top of the sampler provides a means of releasing the jaws by a messenger when the sampler is at the proper place. Two short chains extend from the upper edges of the jaws to two pins in the spring mechanism when the jaws are set at the open position Other details of construction appear in Fig 50

In operation, the sampler is attached to a strong rope by passing the latter through the trip mechanism and knotting it securely below the underlying plate The sampler is then lowered into the water until it rests on the bottom Its own weight is usually sufficient to sink it in the mud for much or all of its height. After a short time to allow for settling, the messenger is sent down on the rope causing the jaws to close and bite out a sample If the sampler is in good condition this sample can be drawn to the surface without loss and without any contact with overlying water. On arrival at the top the sample is delivered into screens, containers or elsewhere by merely pulling up the jaw chains.

This sampler is especially adapted for use in soft, finely divided mud, muck, ooze, submerged marl and fine peaty materials. It will not function on sand bottoms since the springs are not strong enough to force the jaws closed, also fine grains of sand get between the sides of the box and the closely opposed sides of the jaws, preventing the latter from closing This difficulty may appear even in muds having some intermixture of fine sand The presence of hard objects (sticks, partly decayed leaves, clams, stones) may cause difficulty by getting between the jaws. Ordinarily the instrument is useless on hard bottoms

This sampler has been modified in various ways to suit special purposes. For example, it may be made in a tall form in order to provide a better chance of securing the uppermost, fine, bottom materials Such a tall form is sometimes equipped with a series of regularly spaced, horizontal slits through which thin metal sheets resembling the shutters on a camera plate holder can be inserted thus dividing the sample into horizontal strata which can be delivered one at a time, thus making possible a study of stratification of materials and vertical distribution of organisms. Both the standard and the tall forms are sometimes equipped with a brass screen of selected mesh which covers the upper end of the instrument just below the lids Such a screen is looked upon by some workers as a means of preventing the overspill loss of organisms and coarser materials by the sampler sinking into the mud deeper than its own height However, when a sampler is so screened, it must be used with care since if lowered too speedily into a bottom the passage of watery mud through the screen may not equal the speed of lowering and then there is a danger of underspill

at the bottom opening The size of mesh of such a screen must be selected with care and preliminary tests of a sampler so equipped should be conducted in the laboratory before it is used in the field.

General Considerations

a All nuts must be sealed into place with solder to prevent loss in the field.

b. In attaching the rope to the sampler, care must be taken to make a close, secure knot below the supporting plate with the rope end worked into the knot, otherwise the loose end may interfere with the closure of the upper lids

c When lowering the sampler into the water, it should be started down in a vertical position and then not dropped too rapidly, otherwise the open sampler will tend to descend in some diagonal direction When lowered properly, the sampler will meet bottom in the correct position.

d. Ekman samplers of larger sizes (9 × 9 in or larger) when loaded are heavy and ordinarily should be used with the aid of a hoist (Fig 51)

e While this sampler, as usually built, is sturdy and will function indefinitely, damage in the form of bent or dented sides, jaws, and lids is likely to result in leaks, seriously impairing its usefulness Hence in use, impacts with the boat and other objects should be avoided.

f An Ekman dredge may be used at any depths in inland waters.

g The Ekman dredge is suitable both for qualitative and quantitative work

PETERSEN DREDGE

The Petersen dredge is now widely used for taking samples on hard bottoms, such as sand, gravel, marl, clay, and similar materials. This sturdy dredge is usually built of iron and so constructed that both by its own weight and by the leverage exerted by its closing mechanism it bites its way into hard bottoms deep enough to secure satisfactory samples. The principal features of construction appear in Fig. 52. It may be made in any desired size and weight. For ordinary uses one which weighs 35 lb. empty and which may be loaded with weights bolted to the outer surface of the jaws to a total weight of 70 lb. is recommended. Since the total weight is markedly increased when the instrument acquires a sample it is usually necessary to operate it with a hoist (Fig. 51). A dredge of the size just mentioned will enclose an area, when open, of about 0 08 sq m The weight of its load depends upon how nearly it fills and upon the character of the bottom materials One of its virtues is simplicity of construction and operation Barring accidents, such a dredge will last indefinitely. The tripping device consists only of a horizontal locking bar which holds the

dredge open until it reaches the bottom and the tension is taken off the cable. Then the upper bar drops at its free end and the locking bar falls out of the notch in the end of the upper bar. Tension on the cable now exerts a closing motion on the jaws by pulling on the ends of the crossed bars, a motion which not only closes the jaws but tends to force them deeper into the bottom.

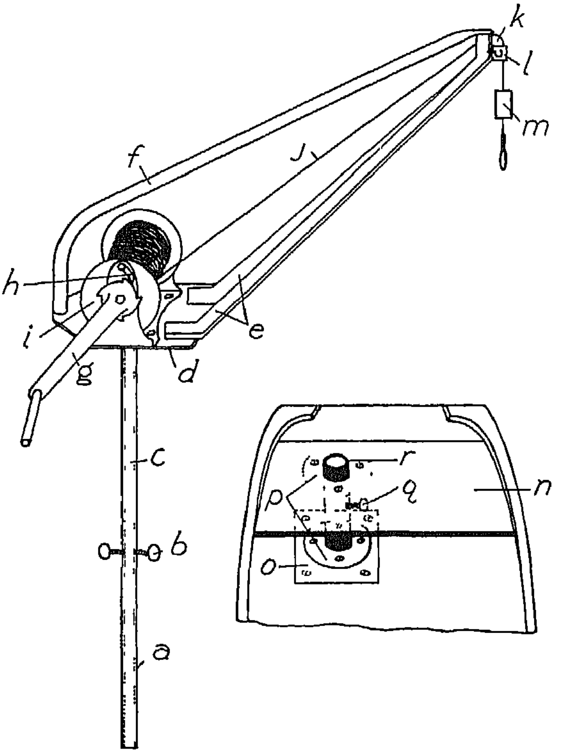


FIG. 51. A crane suitable for lifting limnological sampling apparatus, designed by Brown and Ball, 1940. Originally devised for use on rowboats, it can also be adapted for launches, scows, and other larger craft. (*Left*) Side view of crane. (*Right*) Stern of rowboat showing attachments for crane. (*a*) 1¼-in. pipe, 30 in. long, not fastened at either end. (*b*) Set screw to lock davit to fixed vertical rod. (*c*) Pipe, 30 in. long, attached to plate *d*, is turned to fit inside *a* and acts as bearing for *a*. (*d*) 3/16-in. steel plate, 7 in. wide and 9¼ in. long, with two truncate corners. (*e*) ¾ × ⅞-in. angle irons, 27 in. long. (*f*) ½-in. pipe, 37¾ in. long. (*g*) Lever handle, 10¼ in. long. (*h*) Dog. (*i*) Reel, 3 × 6-in. drum, known as "Sasgen small puller, capacity 300–600 lbs." (*j*) ⅛-in. steel cable, with 6 twisted strands and cord center. (*k*) 1¼-in. ball-bearing pulley. (*l*) Guard with hook to suspend messenger when latter is not needed. (*m*) Messenger. (*n*) Rear boat seat. (*o*) ¼-in. plate, 8 in. square. (*p*) Pipe flange to fit 1½-in. pipe *r*. (*q*) Set pin to hold pipe *a* in position. (*r*) 1½-in. pipe which acts as bearing for vertical arm *a*. (Explanation largely quoted from Brown and Ball.)

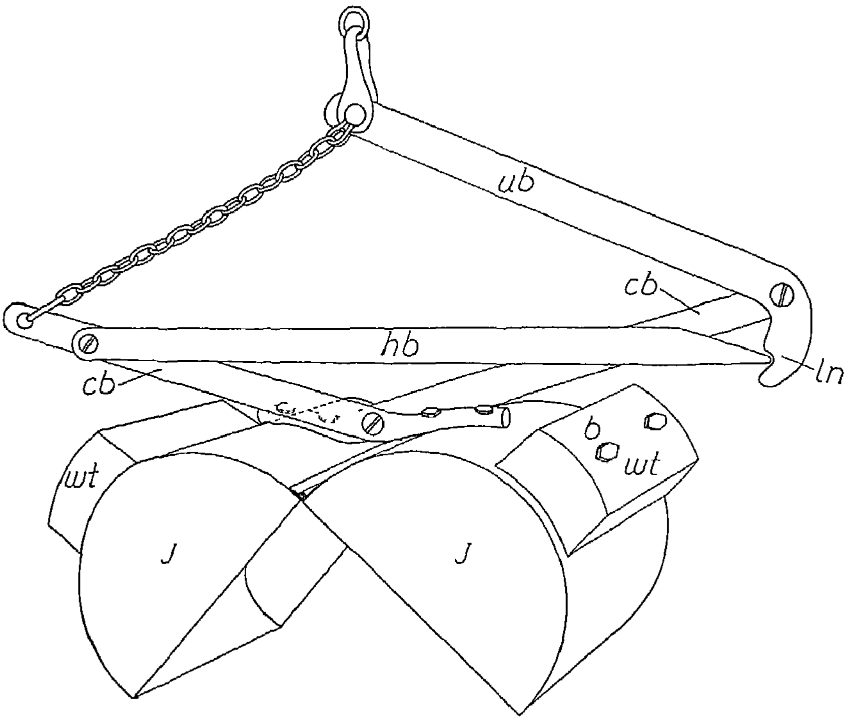


FIG 52 Figure showing principal features of construction of Petersen dredge (*b*) Stud bolt for fastening weight to jaw of dredge (*cb*) Cross bar (*hb*) Horizontal locking bar (*j*) Semicylindrical jaw of dredge (*ln*) Locking notch (*ub*) Upper bar (*wt*) Weight bolted to dredge jaw

General Considerations

a. Most Petersen dredges are of such weight that they should be operated on wire cables of suitable size and tensile strength

b In spite of its vigorous bite there are limits to the sampling capacity of any Petersen dredge It must not be expected to cut through sizable sticks and similar objects or to secure samples from rocky bottoms

c Provided sufficient lifting power is available, metal weights of various magnitudes may be added to the dredge

d If the dredge is constructed of iron, it should be kept well painted to prevent rusting When stored for considerable periods of time, a thorough coating of oil or petrolatum is recommended. This treatment should include all surfaces, joints, bolts, and stud-bolt holes if the latter are left open

e. This dredge is satisfactory for both qualitative and quantitative work

OOZE SUCKER

A useful instrument for securing samples of that fine ooze layer which usually constitutes the uppermost part of the bottom deposits is an ooze sucker modified by Moore (1939) from an original design by Rawson. The principal structural features of the instrument may be seen in Fig 53 The brass ring at the base of the instrument is about 15 in in diameter and has two functions (a) to insure that when the instrument arrives at the bottom it will stop sinking in the proper position, and (b) it aids in keeping the instrument in the upper part of the ooze layer A bridge composed of two parallel rods extends from one side of the ring to the other and supports the sampling mechanism, the tripping device, and the attachment ring The lowermost part of the sampling mechanism is a shallow funnel the broad end of which is directed downward and covered by a brass, 20 meshes-to-the-inch screen the function of which is to exclude very coarse materials that might clog the collecting tube Six small holes, about 3 mm in diameter, through the wall of the funnel provide for the passage of water through the funnel while it descends to the bottom The funnel is attached to and opens into the brass tube which in turn bears at its upper end a large ovoid rubber bulb The funnel tube and bulb mechanism can be disassembled and reassembled in a short time Two large flat plates are

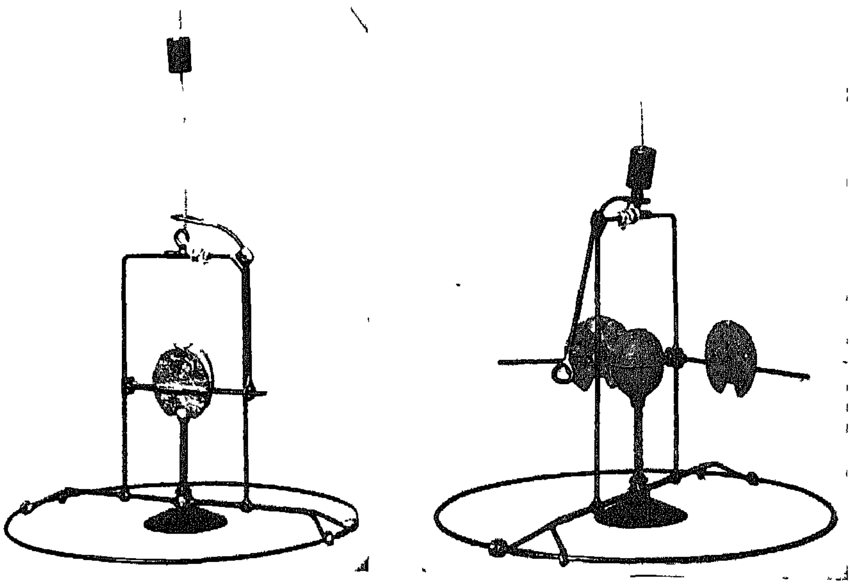


FIG 53 Ooze sucker. (*Left*) Sampler shown with compressor arms closed (*Right*) Sampler with compressor arms released by messenger (From Moore, 1939)

carried on two swinging horizontal arms. When the rubber bulb is in place these flat plates, brought together, squeeze the bulb and temporarily eliminate its inner space. The ends of the two horizontal swinging arms are then caught within the ring of the tripping device, the rope is passed through the other ring of the trip and tied into the supporting ring, and the sampler is ready to be sent to the bottom.

In operation, the sampler is lowered to the bottom and allowed to rest for a moment, then a messenger, sent down the rope, strikes the upper end of the trip releasing the ends of the horizontal swinging arms and allowing the rubber bulb to expand to its normal shape. The bulb thus sucks up a load of ooze through the funnel and tube. On arrival at the surface, the bulb is gently twisted off the tube, its load of ooze delivered wherever desired by squeezing it out, and all residues are thoroughly washed out by repeated squeezings of the bulb partly submerged in water.

General Considerations

a. This instrument finds its greatest usefulness in qualitative work.

b. The sampling mechanism is so constructed that funnels of different sizes, screens of different mesh, and bulbs of different capacities may be used interchangeably.

c. The general delicacy of the instrument demands that it be carried and stored in a specially made case.

VERTICAL CORE SAMPLER

A simple, effective core sampler of the type illustrated in Fig. 54 is especially suitable for bottom sampling which involves consideration of bottom stratification. It consists essentially of a brass tube with a detachable steel nose on the lower end and a weight and valve on the other. The valve permits the free passage of water through the sampler as it descends but as it is hauled up the water pressure automatically keeps it securely closed. The over-all length of the sampler is 60 cm. When the steel nose at the lower end is removed, a glass tube, 48.4 cm. long, inside diameter of 2.2 cm., and open at both ends, is inserted into the brass tube and the steel nose replaced. In operation, the sampler, attached to a rope, is allowed to fall rapidly through the water and imbed itself in the bottom. It is then hauled to the surface, a cork is placed in the bottom opening of the sampler, and the glass tube with its enclosed and undisturbed core of bottom deposit is removed by unscrewing the steel nose. The area of the transverse section of the sample so taken is 3.8 sq. cm.

The general usefulness of this instrument has been extended by additions and accessories designed by Moore (1939). In soft bottoms the sampler imbeds itself properly and without difficulty, but on harder bottoms additional weights must be provided. Such weights may be con-

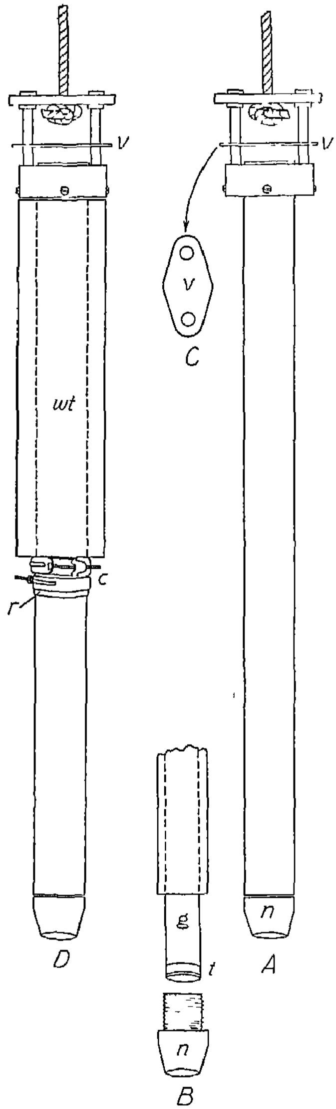


FIG 54 Vertical core sampler (A) Side view of sampler as usually used. (B) Lower end of sampler with steel nose unscrewed and dropped down, also showing lower end of glass tube dropped down out of main tube of sampler (C) Top view of valve (D) Side view of sampler with weight in place for use in more resistant bottoms. (*c*) Hose clamps holding weight in place. (*g*) Glass tube. (*n*) Steel nose of sampler (*r*) Sheet of rubber between clamps and glass tube (*t*) Strip of adhesive tape about end of glass tube. (*v*) Valve. (*wt*) Cylindrical, hollow weight which slips over main tube of sampler and is held in place by hose clamps

structed as follows· a collar consisting of two pieces of iron pipe, one inside of the other and the space between them filled with lead, is slipped over the brass tube of the sampler (Fig 54), pushed to the topmost position and held in place by hose clamps Properly weighted, the sampler will secure samples even from hard sand bottoms Empty glass tubes and tubes containing cores may be carried by a field case as shown in Fig 55.

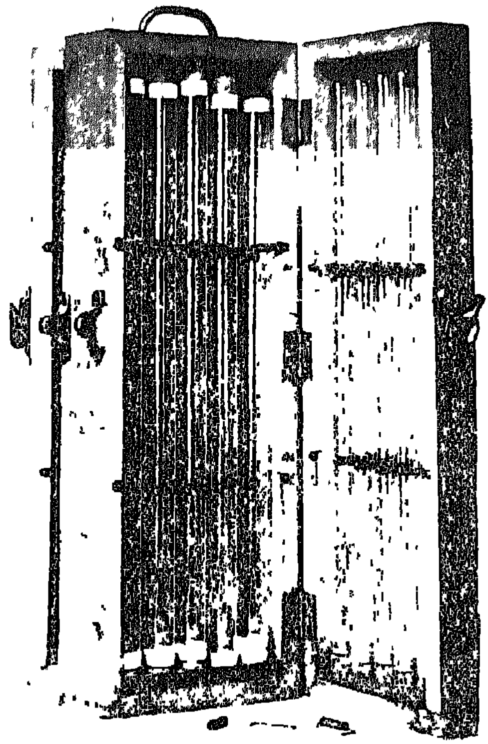


Fig 55 Field case for extra glass tubes used in vertical core sampler (From Moore, 1939.)

When brought into the laboratory, the cores may be treated in any desired way Moore's method for studying the stratification and vertical distribution of materials in the cores is as follows A close-fitting piston *p* (Fig 56) is inserted into the lower end of the glass tube containing the core A rubber cup *c*, 6 cm in diameter, 3 cm high, and with a hole 2 2 cm in diameter in the bottom, is slipped over the upper end of the glass sampling tube until its rim is about 2 cm below the top of the tube This provides a watertight trough around the upper end of the tube Any clear water above the bottom deposits in the glass tube is gently siphoned off

By means of the piston the core is then pushed up the tube until its upper surface is just at the level of the upper end of the tube. Then the first centimeter of core, or any other desired unit of depth, is pushed up by the piston and spills over the end of the tube into the rubber trough The top is leveled off by passing a knife or flat blade across the end of the tube This material is then removed from the cup by means of a small bulb syringe and the cup washed with tap water The next vertical unit of the core is then collected in the same way, and so on until the sectioning of the core is completed The base which serves as a support for the glass tube may be made from a plumber's rubber suction cup

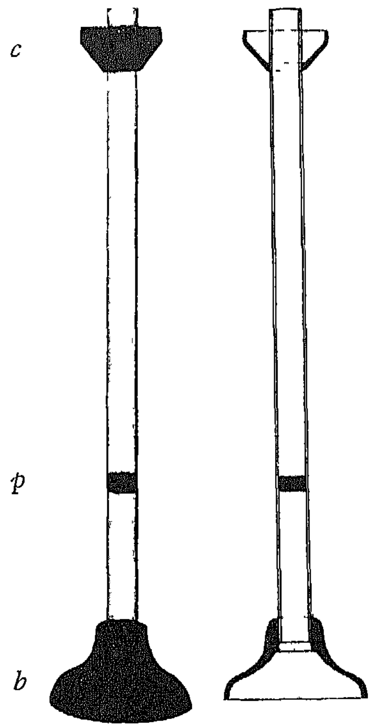


FIG 56 Apparatus for sectioning cores of bottom deposits Figure to right shows longitudinal section of glass tube and supports (*b*) Rubber base for supporting glass tube. (*c*) Rubber cup on top end (*p*) Rubber piston (stem not shown) (From Moore, 1939)

General Considerations

a It has not yet been satisfactorily determined to what extent this kind of a sampler compresses the core linearly, but it is believed that any compacting of cores, if and when it occurs, is not serious for most limnological purposes

b Only unusually watery cores fail to remain in the sampler when hauled to the surface

c There is no evidence that when the sampler is used properly there is any consequential mixing of materials along the sides of the glass tube when the sampler sinks into the deposit or when the core is displaced in the glass tube by a piston

d A strip of adhesive tape about each of the two ends of the glass tubes insures better fitting within the brass tube of the sampler and also offers greater protection against breakage

OTHER BOTTOM SAMPLERS

PEAT BORERS Various types of peat borers are available on the market Certain ones are useful to the limnologist in exploratory work on bog

lakes, marl lakes, and the soft bottoms of the littoral and sublittoral regions of lakes in general.

DEEP-CORE SAMPLERS For a description of equipment and technique for deep-core sampling in lake and stream deposits, the reader is referred to Wilson (1941).

BOTTOM SAMPLING

In the collection of bottom samples for physical analyses, the plan used must take into account the following features· (a) general purpose of whole project; (b) nature of bottom, i e., kind of materials and degree of uniformity, (c) kinds of analyses to be made, and (d) utilization of results.

It is imperative that every effort is made to insure that samples are as *truly representative* of the whole area as possible. This will depend largely upon the good judgment of the operator since by the very nature of the problems involved no definite rules can be formulated in advance Size of the individual sample must also be determined by the nature of the plan and the physical character of bottom materials Unfortunately there seems to be no specific answer at present to the time-honored question as to exactly how many samples must be taken to make the sampling satisfactory Ordinarily one sample has little or no value and as many as practicable must be provided.

Horizontal sampling over the selected area may be accomplished by the random sampling method executed in a completely random way or by the distribution of individual samples along transects which cut across the area according to some predetermined plan.

Vertical sampling, seasonal sampling, and *special sampling* must be planned in accordance with the objects of the work.

Ordinarily, the time interval between sampling and analysis is not as important in mechanical analyses as in certain others although prompt analyses are recommended as the best general procedure since different bottom materials may not behave uniformly in storage.

SCREENS

Suitable screens are standard requirements in many mechanical, chemical, or biological methods for analyzing bottom materials. While screens may be made up in various forms, the following types are suitable for many limnological purposes

GENERAL UTILITY SCREENS One of the best screens for general purposes is built in circular form with flaring sides and having the following dimensions top diameter, 17 in , bottom diameter, 15 in The sides are constructed of heavy galvanized sheet iron having a height of 4 in. above the

level of the screen and an extent of ¾ in below the screen level. The top and bottom rims (Fig 57) are each turned over to surround an iron ring having a diameter of ¼ inch The topmost, 4-in portion and the lowermost ¾-in part are made separately, and when assembled, the circular screen is installed between the two as shown in the sketch. The screen is brass and of whatever mesh is desired. Common and convenient sizes are 10, 20 and 30 meshes to the inch Across the lower surface of the screen and in contact with it are two ¼-in brass rods installed at right angles to each other, intersecting at the center of the screen and fastened to the lower rim of the frame These rods act as supports for the screen when it is loaded In some kinds of work in which the screen must take unusually heavy loads, these cross rods should be of larger size A small ring is installed in the upper rim to which a strong cord can be attached for tie-on purposes This type of construction provides a very sturdy screen, suitable for heavy-duty work, and can be made in any tin shop All parts are soldered securely into place

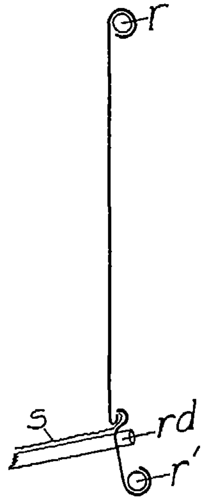


FIG 57. Cross section of side of circular metal screen, showing construction. (*r*) Upper iron ring (*r'*) Lower iron ring (*rd*) Transverse supporting rod. (*s*) Screen.

Another form of general utility screen is made by building a wooden frame in the form of a square or a rectangle with vertical sides 4–6 in high Across one end of this open frame the screen of desired mesh is securely fastened Mechanical support, if needed, may be supplied by installing large-mesh screening immediately below the brass screen Handles on the outside of each end of the frame facilitate manipulation Such screens can be constructed in any desired size and made to nest if different meshes are to be used simultaneously.

Screening may be done by means of canvas or muslin bags into which are sewed large windows of strong grit gauze of suitable mesh. A sample of bottom mud is delivered into one of these bags, the bag closed, the bag and contents submerged in water, and the bag so manipulated that a thorough washing out of the finer contents is accomplished.

TESTING SIEVES When precise results are required, standard testing sieves must be used Such sieves are now made for high accuracy and exact screen analyses In the past, several bases have been adopted for the initial point in screen scaling, some makers using 1 in as the base, and others 1 mm, the scales ranging above and below these units. The U S. Bureau

of Standards standardized the 200-mesh sieve constructed from 0 0021-in wire and having an opening of 0 0029 in, and some manufacturers now adopt this as base for their screens Of the various ratios between the different sizes of the screen scale which have been proposed, that of using the square root of 2, or 1 414, has apparently proved to be the most satisfactory The convenience of this system appears in the fact that in such a series the area or surface of each successive opening in the scale is just double that of the next finer or half that of the next coarser sieve. Thus the widths of the successive openings have a constant ratio of 1 414, while the areas of the successive openings have a constant ratio of 2 Another advantage in this ratio is that by skipping every other screen a ratio of width of 2·1 is secured, by skipping two sizes a ratio of 3 1 is attained, and by skipping three sizes an approximate ratio of 4 1 results

Table 11, Appendix, presents features of certain well-known systems In most series a 200-mesh screen represents the finest sieve When special circumstances demand, a 400-mesh screen may be obtained However, it is recommended (Twenhofel and Tyler, 1941) that for the usual purposes sieves be used for materials the particles of which have diameters which exceed $\frac{1}{16}$ mm, for smaller particles either elutriation or subsidation methods should be employed

Rating of Sieves

Manufacturers of high-grade precision sieves supply the necessary information concerning their products and it may not seem necessary to rate them, but as a safety measure, it should always be done When it is desirable to confirm the rating of such sieves or to rate less precise ones, proceed as follows

Screen a sample of sand which has been dried in an oven to constant weight, pass sample through a single sieve, or a nest of sieves if more than one is to be rated, then take each sieve individually and shake slightly, collecting the grains which pass through the mesh Count a number of these grains and then weigh accurately on an analytical balance those counted and express results in milligrams Calculate the weight of each grain from this result Determine the diameter of each sand grain by the formula

$$\text{Diameter} = 0\ 9\sqrt[3]{w}$$

in which w is weight of one grain in mg and the resulting diameter is expressed in millimeters

This formula gives satisfactory results for sands having a specific gravity of 2 65, an average value commonly used If, however, sands of

some other specific gravity (*sp gr*) are used the diameter of the grains may be computed from the following formula

$$\text{Diameter} = \sqrt[3]{\frac{1\ 91w}{sp\ gr}}$$

From the procedures outlined above it appears that the diameter of the sand grains represents the diameter of the sieve meshes through which the grains passed

Care of Screens

1 Clean screens thoroughly as soon as the task is completed Use a stiff brush to dislodge sand grains If a screen becomes dry before cleaning, it must be thoroughly soaked in water, then scrubbed and rinsed Certain bottom materials when dried in the meshes are resistant to cleaning

2 Avoid passing through screens any collections which may have been treated or preserved in reagents which might cause corrosion

3 Avoid using the supporting cross rods as handles in transporting or in emptying screens

4 Screens should never be overloaded

Mechanical Analyses of Bottom Materials

Assuming that samples have been taken with an adequate sampler and that they are truly representative of the areas under consideration, materials so secured may be treated as described below.

PREPARATION OF FIELD SAMPLES

For gross limnological analyses in which large sieves equipped with the coarser mesh screen are used it is often possible and even desirable to use the entire field sample Even samples of large volume may be screened in their entirety with advantageous results In such instances no special preliminary preparation is required

When graded precision sieves are used, the volume of the field sample determines whether it can be used in its entirety or only in part. If the field sample is small in volume compared to the capacity volume of the sieve the whole sample may be screened, but if the reverse is true, practicality may demand that some kind of subdivision of the sample be made Likewise, in the instance of several samples taken at same time and place, all collections should be assembled into a composite and then subdivided in the manner indicated below

Subdivision by Quartering For this kind of subdivision, proceed as follows

1 Mix thoroughly in same container all materials representing same field sample

2 Deposit on flat surface and spread out into circular, flat mass.

3. Divide mass into quarters, reject two opposite quarters

4 Mix together two quarters retained, if volume of sample so secured is still too great, again spread out into circular flat mass, quarter, reject two opposite quarters, and mix together other quarters, and so continue to subdivide by this same quartering procedure until final sample of proper size is secured. This procedure is suitable for both wet and dry field samples.

SIZE OF FINAL SAMPLE The size of the final sample must be governed by several considerations, namely, character of the material composing the sample, size of meshes used in the sieves, capacity of the sieves, time available for the test, and degree of accuracy desired. As a general principle, the use of as large a sample as is consistent with practicalities of the situation is recommended.

WET SAMPLES. Wet samples usually require no special treatment unless the water content is so high that subdivision by quartering described above cannot be accomplished in which instance it is necessary either to pass the whole field sample through the sieves even at the added cost in time and effort, or to resort to subdivision by some other method, as for example, thorough mixing followed immediately by cup sampling.

DRIED SAMPLES If dry samples are demanded, wet field samples should be placed in an oven with temperature maintained at about 105° C. and dried to a weight which is practically constant before they are put through the sieves This treatment is satisfactory for bottom materials containing a large component of sand. However, it may happen that some bottom materials, on being dried, tend to change their physical character, perhaps tend to consolidate, or otherwise undergo changes which make any subsequent dry analyses by graded sieves unsatisfactory. In such instances wet screening is recommended

GROSS ANALYSIS

If only a gross analysis is needed, the collected wet materials may be passed through a vertical nest of three sieves of sizes No. 10, 20, and 30 This passage of materials is facilitated by directing a stream of tap water into the upper sieve (No. 10) in such a way that the finer materials are washed down into the lower sieves. When this washing is completed, the materials in the uppermost two sieves are removed and are ready for whatever form of examination is desired If the material which accumulates in the No. 30 screen does not appear to be well washed, washing may be concluded by treatment with a jet of tap water If screening must be done in the field, lower the sieve with its contents until it is about one-half submerged in the lake or stream water, then give the sieve a vigorous rotating motion by grasping the frame with the two hands 180° apart

and swinging the sieve first one-half turn in one direction and then a like swing in the other, at the same time imparting to the screen a slight vertical up-and-down motion. By this method all of the material passing through the third screen is lost Should this material be desired it must be collected by the addition of another screen of still finer mesh If all solid materials are to be examined, materials escaping through the finest sieve must be collected and passed either through a filter of some suitable type, or through a high-speed centrifuge

For most limnological purposes, final results may be expressed in terms of percentage of the total sample, either by weight or by volume

Analyses with Graded Sieves

Graded sieves are commonly made so that the extended bottom rim of each fits snugly into the top of any other, forming a vertical series Thus sieves may be selected in any desired combination and nested together with the coarsest mesh at the top and the others arranged in a progressively finer series. A whole set so assembled may be operated simultaneously, or the sieves may be used individually and successively.

Different limnological needs demand different procedures in the use of graded sieves and the operator must adapt his practices accordingly. Under all circumstances the underlying purpose is to provide a means of sorting mechanically and differentially the physical components of a sample on the basis of size groups as determined by the sizes of mesh used. The following procedures are presented for their general utility, but it must be understood that still others may be required, depending upon the character of the bottom materials and other conditions.

PROCEDURE NO. 1—WET SIEVING

1 Assemble nest of sieves including desired sizes of mesh graded progressively from coarsest at top to finest at bottom; leave top and bottom open, arrange so that outdrainage from lower screen is properly provided for.

2 Allow excess water, if present, to drain from field sample, weigh final sample and place in top (coarsest) sieve

3 By means of jet of tap water under low pressure, gently wash sample through underlying screens until material no longer leaves lowermost screen, remove uppermost screen and again pass water through underlying screens, making certain that accumulated material in each sieve has been adequately washed, remove next sieve and proceed as before until all are so treated

4 Carefully remove all material retained by each sieve, allow any excess water, if present, to drain out, weigh material from each sieve

5. Calculate per cent by weight of material passing each sieve as follows

$$p = \frac{s - (w + W)}{s}$$

in which

p = per cent of material passing individual sieve
w = weight of material retained by individual sieve
W = combined weights of all materials retained on all coarser screens above
s = total weight of original sample

Because of difficulty of reducing water content in all screened material to same level, this method does not yield results of high precision For general purposes the results are useful. Some bottom materials are not readily handled in this manner

PROCEDURE NO 2—DRY SIEVING

1. Assemble nest of sieves as in Procedure No 1, weigh dry sample and place in top sieve

2 Give whole nest of sieves an initial shaking of about 3–4 min.

3. Remove topmost (coarsest) sieve from nest and shake separately but directly over sieve next below to complete screening, continue shaking until no material passes through screen, proceed in same fashion with other sieves.

4 Weigh materials retained by each sieve and calculate per cent by weight of material *passing through each sieve* by the use of the same formula given in Procedure No. 1

PROCEDURE NO. 3—WET-AND-DRY METHOD

1. Assemble selected sieves in graded series Deposit sample in *finest* sieve to be used in analysis, place under small, low-pressure stream of tap water and wash until fine materials no longer pass through sieve, collect all material passing through sieve, dry, and weigh

2 Dry and weigh material retained in sieve, add this weight to dry weight of that material which passed through sieve

3. Place dried material (material *retained* by finest sieve) on coarsest sieve, shake until material no longer passes through screen, and collect all materials passing through Transfer collected material to next finest sieve and proceed as before Complete sieve analysis by using successively and in proper order all sieves in series, including that one used in preliminary washing process. Weigh separately materials retained by each sieve

4 Calculate per cent by weight of material passing through each sieve, using same formula as given in connection with Procedure No. 1. (Note

that s in formula is here the sum of (a) the dry weight of the material passing through, and (b) the dry weight of material retained by, the finest sieve used in the preliminary washing process)

If, in sieving, a significant amount of fine material passes through the finest screen in the last step of the analysis, it may be collected, weighed and properly accounted for in the final computation.

GENERAL CONSIDERATIONS

a. The size of a sample for sieve analysis should not be so large that the sieve cannot perform properly Interference with free passage of material through the sieve may result from a sample which is too large

b. Shaking is commonly performed by hand Special machines for shaking samples have been devised

c Manufacturers of graded sieves commonly supply detailed technical information concerning their products.

d. Dried samples of materials which tend to cake or consolidate may require dispersal before sieving

e. For information concerning highly precise methods for the study of bottom sediments, the reader is referred to Twenhofel and Tyler (1941) and similar treatises

Ripple-mark Records

Ripple marks on lake and stream bottoms are indices of certain limnological processes Under some circumstances they may be studied *in situ* in the field, under others, direct study may be difficult or impossible In either instance, permanent records are desirable and sometimes necessary The methods described below were originally designed by Kindle (1917)

Shallow-water Method In water having a depth of 0 3 m or less, plaster of Paris casts may be made as follows The bottom of a wooden box, about 46 × 25 × 15 cm , is removed One edge is beveled all around the periphery This frame is then pressed firmly, beveled edge down, into the bottom surrounding the ripple-mark area to be recorded Plaster of Paris is sifted through a screen until an accumulation of 2 4 cm or more in thickness has been deposited inside the frame Complete protection against any disturbance for one hour must be provided Then the cast may be removed

Deep-water Method When greater depth of overlying water prohibits the use of the method just described, casts may be made with an apparatus the essential features of which are as follows a base in which the cast is to be formed is constructed This base has a diameter of about 40 5 cm , a form like that of an inverted dishpan, and the lowermost edges sharp Just above the edge of the base, short nails are inserted through holes, most of the length of each nail extending into the interior

of the base On top of this broad circular base is mounted a 2.5 quart cylindrical tin reservoir the top end of which is closed by a cap resembling that of a milk can. In the opposite end of this reservoir is a wide short tube which fits snugly into a hole in the center of the base and contains a valve which opens upward Through a small hole in the reservoir cap a string passes from the valve at the bottom of the reservoir to the surface where it can be manipulated by the operator. Two or more valves in the upper surface of the base, so constructed that they will automatically be open during the descent and then closed when on the bottom, facilitate the lowering of the apparatus The reservoir is filled with a mixture of plaster of Paris and water (equal parts of each) and the reservoir cap put into place Then the apparatus is lowered to the desired place by supporting cords and allowed to settle for a moment The valve at the lower end of the reservoir is then opened by pulling the controlling string, and the plaster of Paris mixture pours into the base forming a layer over the area of bottom so surrounded The plaster of Paris mixture must be delivered into place within 5–6 min after it is first prepared since it begins to show signs of setting after 6 or 7 min. One hour is allowed for setting of the plaster; then the cast may be lifted, the small nails in the base preventing its escape If the apparatus must be left during the hour required for setting it should be marked with a buoy

Another device useful in deeper waters gives information on the spacing or amplitude of ripple marks A thin piece of sheet iron or zinc, about 50 cm square, is suspended by four cords attached at the four corners. These cords are united into a single cord by means of which the plate is lowered after being suitably weighted The lower surface of the plate is coated with petroleum jelly When lowered to the bottom, allowed to rest there momentarily, and then raised to the surface, the plate will show lines of adhering sand representing the crests of the ripple marks.

Firmness of Bottom

No method of measuring firmness of bottom has yet been adopted as a standard procedure. The degree to which bottom materials pack under natural conditions has limnological significance and some method of measure is needed The method described here makes use of the principle that this firmness (degree of packing) of bottoms in which the predominating materials are sand, silt, organic deposits, gravel, marl, and clay may be expressed by that force which is necessary to cause the penetration to a measurable depth of an object having known weight and cross section in a selected unit of time Equipment for this purpose may be assembled as follows

Choose a straight iron rod, 1.2 cm in diameter, and round off one end to the form of a hemisphere, using rounded extremity as the zero end,

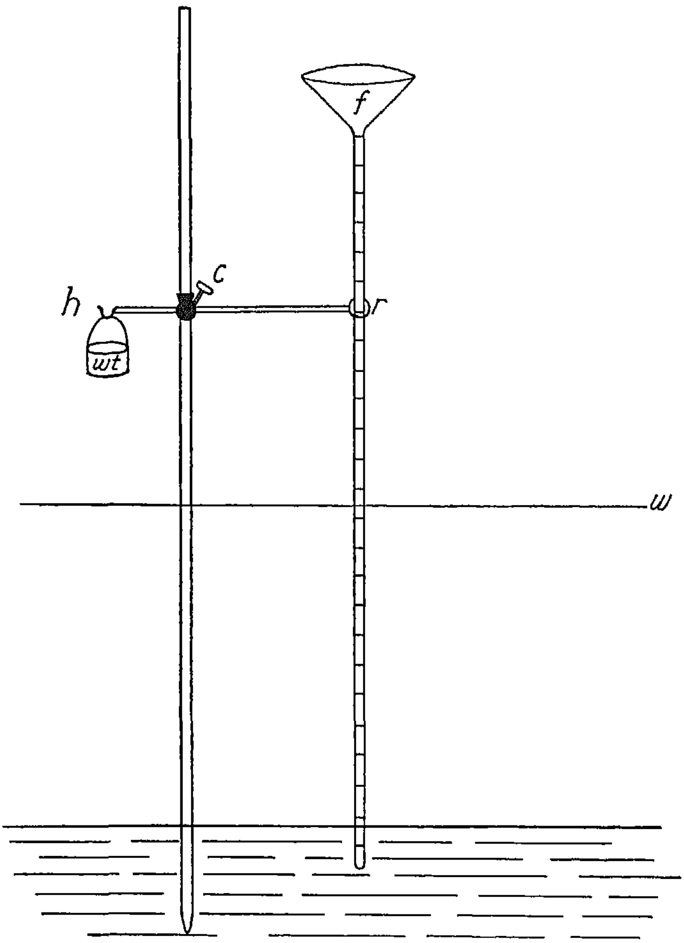


FIG 58 Apparatus for measuring firmness of bottom (*c*) Ring-stand clamp (*f*) Funnel for receiving weights (*h*) Hook on horizontal bar for holding supply of weights. (*r*) Ring on horizontal bar (*w*) Water line (*wt*) Pail holding weights

graduate the rod in some system of convenient, linear units by cutting shallow rings around the rod with a pipe cutter or some similar instrument. Fasten a metal funnel securely to the top of rod as shown in Fig. 58. Select another piece of rod of similar size and having length greater than the graduated rod, taper one end to a point, by means of an adjustable ring-stand clamp, secure to this rod, and at right angles to it, a section of rod about 1 m long in the free end of which is a metal ring having a diameter of about 2.4 cm , insert a hook in opposite end of this transverse rod. In operation, the supporting rod is sunk firmly into the bottom at

the point to be tested and in a vertical position, the transverse rod is adjusted to the proper height above the water surface *w* and the pail containing the weights hung on the hook *h*, the graduated rod is thrust vertically through the supporting ring *r* and allowed to come to rest with lower rounded tip in bottom materials Weights are added to the funnel *f* until the sinking (penetration) is considered to be a sufficient test For ordinary purposes the results may be expressed in *distance of penetration under the weight used* per unit of time for a rod of stated size The *weight used* is computed as $wts + (R - b)$ in which wts = the weights added in the funnel, R = weight of the graduated rod, and b = buoyancy of water exerted upon the graduated rod

GENERAL CONSIDERATIONS

a. If desired, the rods may be made sectional and thus adapted to deeper water. However, the method is obviously limited in general to shallow depths

b The supporting rod may be built with a metal tripod foot thus avoiding the necessity of setting the rod into the bottom.

c A sturdy transit tripod with a large opening through its metal head serves very well as an improvised support for the graduated rod However, if the buoyant effect of the water on the wood legs of the tripod is too great it will be necessary to load the tripod

d. Keep rods well coated with oil, if of iron, to prevent rusting Brass is preferable if it can be provided

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(For Chapter 13)

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Part III

Chemical Methods

In this section, only a limited group of chemical methods is presented The methods chosen are those needed for an initial entry into limnological work, also those commonly used in routine limnological procedures Inclusion of other chemical methods is made unnecessary by the existence of an authoritative and readily available work, the well-known "Standard Methods for the Examination of Water and Sewage," 9th ed, 1946, American Public Health Association, which covers the field adequately and extensively Several other similar works also exist Hence more extensive consideration of chemical methods here would merely result in unjustified repetition The less experienced worker in limnology should be warned that, while "Standard Methods" mentioned above is a leader among works of its kind, it is written for the professional chemist with consequent omission of much detailed and elementary material

SELECTED CHEMICAL METHODS

Samplers

Scrupulous care must be exercised in the choice of means whereby samples of water for chemical analyses are secured since the water (a) must be taken at a positively known depth, and (b) must be brought to the surface in strictly unmodified condition Any sampler used for this purpose must, if properly operated, guarantee these results, otherwise serious error will result In the past, many samplers of various designs have been constructed, some of which are still used with satisfactory results

KEMMERER WATER SAMPLER

The modified Kemmerer water sampler, illustrated in Fig. 59, is now so generally used that it has virtually become a standard instrument When in good condition and properly used, it meets the two general requirements mentioned above In addition it has the virtues of simplicity of construction, convenience, small bulk, slight weight, and modest cost All parts save the rubber valves are made of brass and the number of working parts is very small It is commonly constructed in three different sizes, namely, 1200-, 2000-, and 3000-cc capacities, the first being best suited for general limnological purposes With the exception of differences in the tripping mechanism, improvements made upon the original Kemmerer design have now produced an instrument of one standard type. In operation, the open sampler is lowered on a graduated rope to the desired depth A messenger is sent down the rope causing the release and closure of both the upper and lower valves These valves when seated are watertight, furthermore, the instrument is so constructed that when closed the entire weight of sampler and contents is carried upon the lower valve, further insuring its complete closure In spite of the fact that the instrument does cause a slight disturbance of the water as it sinks, practical experience has shown that such influence is negligible.

General Considerations

a The chief disadvantage of the Kemmerer sampler is its relatively small capacity thus requiring repeated trips to the selected depth whenever large quantities of water are desired

b. When in storage the sampler should be hung from a hook in vertical

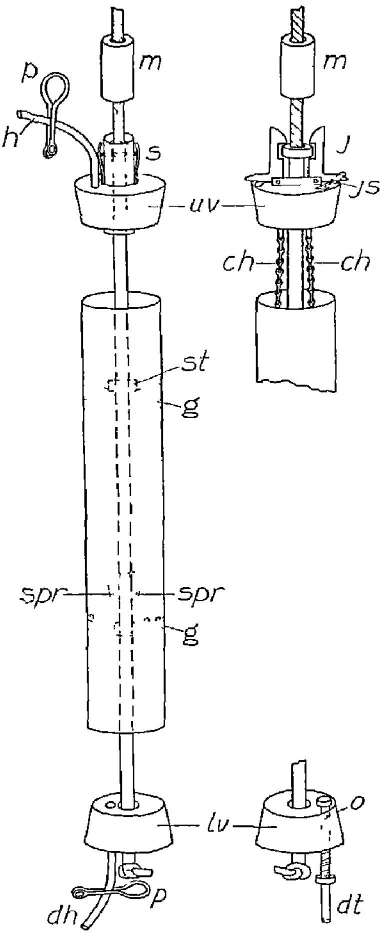


FIG. 59. Diagram showing structural features of modified Kemmerer sampler (*Left*) View of complete sampler with valves open (*Top right*) Another type of construction of upper valve and tripping device (*Bottom right*) Another type of construction of lower valve and drain tube (*ch*) Chain which anchors upper valve to upper interior guide (*dh*) Rubber drain tube (*dt*) Brass drain tube (*g*) Interior guide fastened to inner surface of body of sampler (*h*) Rubber tube (*j*) Jaw of release (*js*) Jaw spring (*lv*) Lower valve (*m*) Messenger (*o*) Opening into interior of drain tube (*p*) Pinch cock (*s*) Upper release spring operating on horizontal pin one end of which fits into groove on central rod (*spr*) Spring fastened to lower internal guide and operating in groove on central rod to provide lower release (*st*) Stop on central rod (*uv*) Upper valve

position with the valves open. Samplers stored horizontally are more subject to accidents, and storage in the closed form may injure the seating surfaces of the valves

c This instrument must be protected against blows on the ends of the brass cylinder which may cause them to be knocked out-of-round This is a common cause of sampler leakage and leakage leads to serious errors

d Leakage may also arise from a bent central rod When this rod is bent, it is usually best to replace it with a new one

e It is necessary to replace the large rubber-stopper valves whenever they become worn or hardened from aging As these samplers are now made this is not a difficult operation

f In the field such samplers should be carried in suitable field kits in order to avoid accidents

g For special purposes these samplers can be made in forms either shorter or longer than the conventional ones

h. One type of tripping device (Fig 59, *left*) is of such a construction that when all springs are carefully adjusted no messenger is required but the instrument may be closed at the selected depth by giving a sharp, sudden jerk on the rope Such an arrangement may be convenient particularly in the shallower waters.

PUMP AND HOSE METHOD

Samples of water from various selected depths and satisfactory for chemical analyses may be secured by the pump and hose method provided certain conditions are fulfilled and the limitations are understood This method requires the use of a suitable pump of the type which, when fully primed, has no leaks and contains no air spaces Such a pump may be any form consistent with the demands of the particular kind of sampling desired Suitable pumps vary from the small plunger pumps which are held in the hand, through medium sized "clock" pumps, to the larger power-driven types The hose must be appropriate to the size of the pump used, must be free from leaks, and should be graduated, if inelastic, to facilitate depth readings It may be necessary to weight the lowermost end of the hose in order to insure that it descends vertically through the water

In addition to cumbersomeness, weight, difficulties of handling, and cost, the pump and hose method has one fundamental weakness, namely, it may fail to meet the requirement of sampling water from one narrow, definitely known stratum When drawn into the open lowermost end of the hose, the water moves into that region from all directions and continues to do so until pumping ceases There is no way of knowing from what distances, radially from the end of the hose, the water has come This might not appear serious if only small quantities of water are needed but it must be remembered that before any samples can be taken pumping

must proceed until the whole system is filled with the water from the selected level, also that in taking series of samples at successively lower depths the water already filling the system must all be pumped out and the new water take its place whenever the hose is lowered to the next sampling depth These pumpings necessitate the removal of a considerable quantity of water from each depth How much water has come from other positions and levels in the sphere of inflowage about the end of the hose is uncertain If sampling from a wider stratum presents no difficulty the method will be adequate

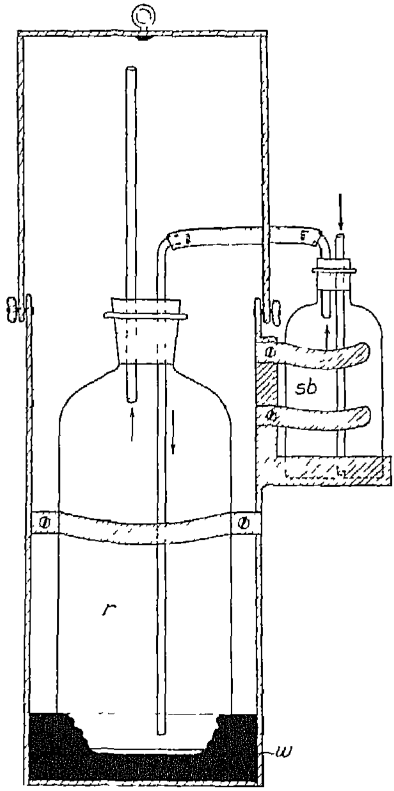


FIG. 60 Side view of Hale's water sampler. (*r*) Reservoir bottle (*sb*) Sample bottle. (*w*) Weight at bottom, shown partly cut away in front. Arrows indicate direction of flow through sampler when lowered into water

HALE'S WATER SAMPLER

In case it is necessary to improvise means of securing samples for chemical analyses, Hale's water sampler can easily be assembled from ordinary laboratory materials and, if its limitations are understood and if it is operated properly, samples suitable for ordinary purposes may be secured Fig 60 indicates the general features of construction The reservoir bottle (*r*) must have a capacity several times (preferably six or more) that of the sample bottle (*sb*). The top of the outlet tube in the reservoir bottle must be at a higher level than the top of the inlet tube in the sample bottle —a condition which insures that the water will flow through the system in the proper direction At the bottom of the frame which carries the reservoir bottle is a base of lead (*w*) or some other suitable heavy substance, shown partly cut away in Fig 60, which facilitates the rapid sinking of the sampler to any desired depth

When this sampler is submerged, water enters the intake tube of the sample bottle, filling it from the bottom and displacing the air, then water passes over into the reservoir bottle until it also is completely filled In this process the sample bottle has been overflowed several times and, at the

cessation of flow, contains the last portion of water to enter the apparatus, thus providing a good sample Care must be taken to insure that the apparatus remains at the sampling position long enough to completely fill the reservoir bottle, otherwise flowage will continue while the outfit is being brought to the surface with resultant entry of water from other levels The time interval necessary for the filling of any apparatus of this kind should be determined in a tank in the laboratory before it is used in the field. To the interval so determined should be added a certain amount of additional time as a margin of safety

Because of the construction of the apparatus, water begins to enter the system as soon as it is lowered below the surface If samples are being taken at considerable depths, it is necessary to lower the outfit as fast as possible so that the amount of water entering at different positions above the desired sampling level will be minimal However, since the sample bottle is overflowed several times by water entering from the proper sampling level, that which entered on the way down is displaced in the first overflow and in no way affects the final sample Once the system is completely filled, no water can enter while the apparatus is being brought to the surface, thus no error is introduced on the return trip.

The sample bottle must be one of the regular sample types selected for water analyses so that when detached from the Hale apparatus the analysis can proceed without any transfer of the water to another container. A narrow-neck bottle with about 250-cc capacity and with ground-glass stopper is a good type since, on detachment from the frame of the apparatus and the necessary withdrawal of the first stopper and its glass tubes, the water level in the bottle is such that the glass stopper can be dropped into place with a small overflow and no inclusion of air bubbles. In rapid transfer of the two stoppers momentary exposure of the small amount of water surface in the neck of the bottle leads to no appreciable error

As usually set up, the Hale apparatus carries but one sample bottle However, if it is desirable to secure more than one sample from the same level and at the same time, it is possible to add a limited number of other bottles by providing a much larger reservoir bottle, and by supplying the necessary additional supports The sample bottles must be coupled *in series*, so that the water flows through all of them before entering the reservoir bottle. Additional time must be allowed for completing the filling at the sampling position This multiple arrangement must be tried out carefully in the laboratory before taking it into the field It may be necessary to increase the difference in height level between the intake opening of the first sample bottle and the top of the outlet tube in the reservoir bottle in order to provide enough difference in hydrostatic pressure to insure prompt and certain flowage through the series of bottles.

General Considerations

a. Inside surfaces of bottles, tubes and stoppers must be of such character that there is no opportunity for air bubbles to become trapped.

b. Sample bottles of smaller capacity may be used if the occasion warrants.

c. In order to avoid loss of time due to breakage of glass parts, extra glass tubing, rubber tubing, and a file should be carried in the field.

d Proper time allowance for filling at the sampling level is of prime importance Since the process of filling cannot be observed by the operator, except in very shallow water, the only certainty that the sample will be trustworthy is that which comes from leaving the apparatus in the

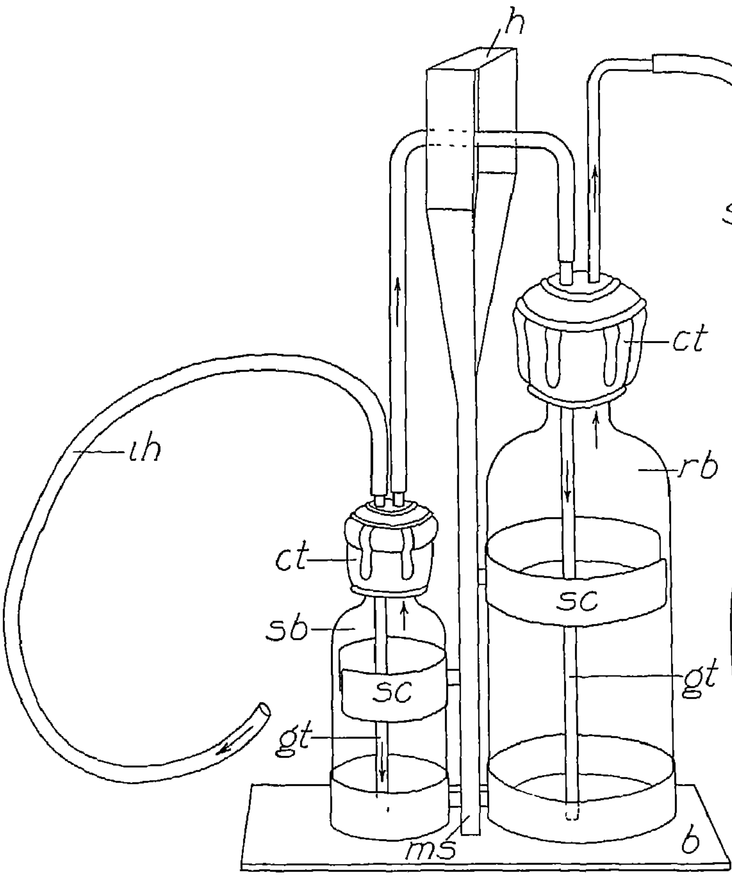


Fig 61 Irwin's sampling device for securing water samples of small volume. (*b*) Base. (*ct*) Rubber church tip. (*gt*) Glass tube (*h*) Handle (*ih*) Intake hose (*ms*) Metal support. (*rb*) Reservoir bottle (*sb*) Sample bottle. (*sc*) Spring clamp. (*sh*) Suction hose.

selected position for the predetermined filling interval plus a margin of safety In case of doubt it is better to double the filling interval and thus be assured that the sample is safe

IRWIN'S SAMPLING DEVICE

The usual kinds of equipment cannot be used for securing water samples from very small, shallow pools Irwin (1942) devised means of securing samples from such pools, especially those containing large quantities of debris Fig 61 indicates the principal features of its construction It employs the main features of Hale's sampling apparatus (p 202) but is adapted for securing samples of small size as is demanded in situations where most or all of the exposed water must be taken in order to secure a usable sample. An intake hose is fitted to the smaller bottle and a suction hose to the larger one. When ready for use, the free end of the intake hose is placed in the water, then by taking the free end of the suction hose in the mouth and withdrawing air both bottles are filled The sampling bottle (smaller one) is overflowed at least six times its own volume.

In order to make it possible to obtain usable samples from water containing much trash, Irwin devised a special strainer shown in Fig 62 This device consists of a copper cylinder 5 cm. deep and 13 cm in diameter It is open at the top and covered on the bottom with fine-mesh copper screen except for the central region which is occupied by a shallow, cylindrical cup 8 mm deep and 5 cm. in diameter. In the vertical sides of the main cylinder several circular windows are cut out and covered with fine-mesh

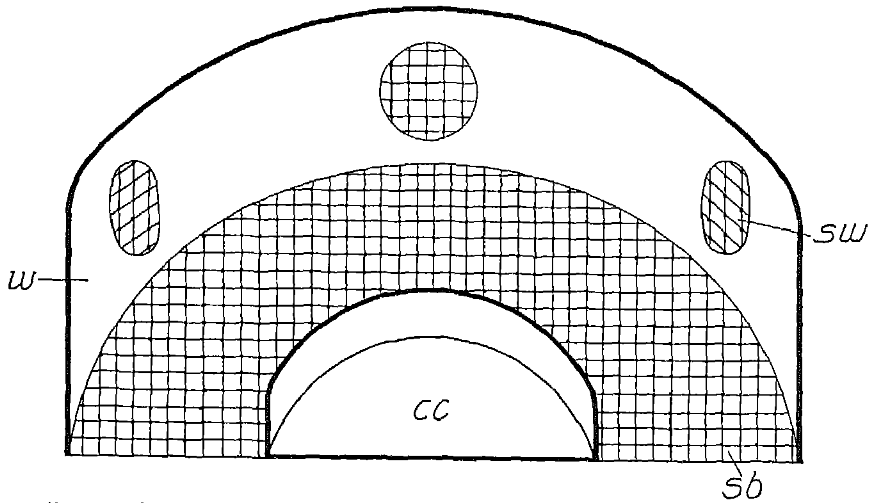


FIG 62 Sectional view (one-half) of Irwin's strainer used in taking water samples from small shallow pools containing debris (*cc*) Central cup (*sb*) Screen bottom (*sw*) Screen window in side wall. (*w*) Side wall of copper cylinder

copper screen. When in use, the strainer is placed carefully into the water to be sampled, screen side down, and submerged until outside water surface is above the level of the windows The water enters through the screened bottom and windows and slowly fills, with minimal agitation, the central cup. The end of the intake hose is held directly above the central cup while taking a sample. The size of the mesh used in the screen is determined by the character of the debris to be excluded and the operator must modify the apparatus to meet his particular needs.

Dissolved Oxygen

SAMPLING

The mode of collection of samples for dissolved oxygen analyses must be chosen in advance on the basis of the necessities of the situation All subsurface samples should be taken with a sampler which will meet the requirements stated on p 199 The sampler used must be of such construction that its capacity exceeds several times that of each of the individual sampling bottles.

In multidepression lakes it is evident that the dissolved oxygen picture on any one date cannot be determined from a single vertical series of samples taken only in one of the submerged depressions.

Sampling Bottles For ordinary field purposes, a good grade, white-glass, narrow-neck, ground-glass stoppered bottle having a capacity of about 250 cc. is recommended Each bottle should be numbered in some permanent and easily readable way and in some convenient numerical sequence Each bottle should bear its number on two different places to insure against loss of identity in case one number is accidentally destroyed. A number on the side of the bottle and also on the top of the glass stopper provides satisfactory identification Glass stoppers must be ground to fit the bottles, hence the necessity of guarding against the mixing of stoppers and bottles Numbers may be pasted on the glass and then sealed over with two or three coats of shellac. Numbers may also be made as follows cut out squares of heavy canvas of uniform, convenient size, write numbers on same using Higgins Waterproof India ink or Higgins Eternal ink, through small hole in each square fasten tie-on string of strong cord, put squares and tie-on strings into melted paraffin and keep there until thoroughly permeated, attach label to sampling bottles by tying to neck of bottle Metal tags should be avoided

For field transportation and for storage, sampling bottles should be kept numerically arranged in field kits made for that purpose. At the end of each analysis all bottles must be thoroughly rinsed and made ready for the next series

Field Procedure. When a sample is delivered at the surface by a

Kemmerer sampler, the lower delivery tube of the latter is inserted to the bottom of the sampling bottle and the water allowed to flow continuously until the sampling bottle has been overflowed at least three times its total capacity and all bubbles are eliminated. This threefold overflow insures that the first water entering the bottle and making contact with the air originally contained in it has been removed, all of the air has been displaced, and the final bottle of water is truly an unmodified sample Satisfactory control of the overflowing may be provided as follows Determine the length of time required to fill the empty bottle the first time by counting (ordinarily a count of 10 at the rate of 1 per second of time will suffice), then continue overflowing for a count three times the number so determined The delivery tube of the sampler is gently withdrawn at the end of sampling so that before the flow ceases, the bottle is filled to the top of the neck. The glass stopper is immediately dropped into the neck of the bottle in such a way that it displaces just enough water to enable the stopper to seat itself completely but leaving no air bubbles. With a little practice this trick of dropping the stopper into place without the inclusion of bubbles can be easily acquired.

WINKLER METHOD

The Winkler method, or some modification of it, has become the standard means of determining dissolved oxygen and is more widely used in limnology than any of the other methods For most purposes it is convenient and sufficiently accurate Various other methods have been devised some of which are by their very nature strictly laboratory procedures and scarcely adaptable to field operations.

The unmodified Winkler method, to be described first, may be used for waters known in advance to have a very low content of iron, nitrites, or organic matter. For the purer waters (cleaner unmodified water of lakes and streams) it is usually adequate and is simpler and shorter than the Rideal-Stewart modification described later.

Reagents

1 Manganous sulfate 480 g $MnSO_4$ $4H_2O$, or 400 g. $MnSO_4$ $2H_2O$ dissolved in distilled water, make up to 1 l

2. Alkaline-iodide· 500 g NaOH (or 700 g KOH) and 135 g NaI (or 150 g KI) in distilled water, make up to 1 l.

3 Concentrated sulfuric acid sp gr. 1 83–1 84

4 Sodium thiosulfate 6.205 $Na_2S_2O_3$ in freshly boiled distilled water; make up to 1 l This produces a $N/40$ solution Add 5 cc. chloroform Make up fresh solution every 2–3 weeks. Standardize occasionally according to directions given below.

5 Starch solution 5 g of potato starch, ground in mortar with small

amount of distilled water pour into 1 l of boiling distilled water, stir and let settle for several hours; use clear supernatant liquid, add 1 25 g salicylic acid per liter as preservative.

Directions for Standardizing Sodium Thiosulfate Solution Dissolve 0 2454 g potassium dichromate ($K_2Cr_2O_7$), which has been dried at a temperature of 130° C for one-half hour and cooled in a desiccator, in distilled water, make up to 200 cc This gives $N/40$ $K_2Cr_2O_7$ Put 10 cc of this solution into a beaker surrounded by an ice bath, add 1 cc KOH-KI solution (2) drop by drop, rotating beaker at same time Add 1 cc. concentrated H_2SO_4 in same way If odor of iodine is detectable, iodine is being lost and the process should be repeated. Iodine will be released by the KI giving solution a deep color Now titrate with sodium thiosulfate solution (4) until iodine color begins to disappear, then add starch solution as an indicator and continue titration until blue color just disappears Record number of cc thiosulfate used, 10 cc of sodium thiosulfate should exactly neutralize 10 cc of potassium dichromate When this condition is met and 200 cc of water is titrated for dissolved oxygen the quantity of O_2 in cc. per liter is calculated by multiplying number of cc of sodium thiosulfate used for titration by 0 698. However, if condition described above is not met, then sodium thiosulfate solution may be adjusted to meet condition, or another constant may be calculated from results, for example, if 11 cc. of sodium thiosulfate is required to neutralize 10 cc. of dichromate solution, then new constant will be 11/10 times 0 698

Procedure

The first three steps described below must be performed in the field immediately after the sample has been secured Any delay may result in error.

1 Remove stopper from 250-cc. sample bottle containing sample to be analyzed and, by means of long narrow volumetric pipet, add 1 cc of manganous sulfate solution (1) well below surface of water In like manner, add 1 cc of KOH-KI solution (2)

2 Replace stopper and mix sample by inverting bottle several times. Allow precipitate to settle for a few minutes Thorough mixing is required, repeat inversion as safety measure or if doubt exists. After final settling of precipitate, a clear fluid should occupy upper portion of bottle.

3. Using slender volumetric pipet, add 1 cc concentrated sulfuric acid by permitting it to run down neck of bottle, mix well by inverting bottle several times Allow sample to stand for at least 5–10 min.

After the acid has been added and the stopper of the sample bottle replaced, concluding steps of the analysis may be delayed, if necessary, for several hours without appreciable change This makes it possible to avoid titrations on board a boat

4 Transfer 200 cc of sample to porcelain evaporating dish and titrate rapidly with $N/40$ sodium thiosulfate solution until iodine color in sample has been reduced to pale straw color, then add a few cc of starch solution and continue titration rapidly but cautiously until blue color *first disappears* Discontinue titration at this end point Ignore any return of blue color

If very precise results are desired, a correction for the loss due to displacement by the reagents may be made as follows When 2 cc of reagents (manganous sulfate and KOH-KI) are added to a 250-cc. sample the amount transferred for titration should be $(200 \times 250) - (250 - 2) = 201.6$ cc if the amount of the original sample titrated is to be 200 cc However, this correction is not justified in most kinds of limnological work

CALCULATION OF RESULTS. If a 200-cc sample is titrated, the number of cc. of the sodium thiosulfate solution used is numerically equal to the dissolved oxygen content in *parts per million* and no additional calculation is necessary This value, multiplied by 0.698 (or some corresponding standardization value, see p 208) will yield the value in terms of *cubic centimeters per liter* Results in terms of *percentage of saturation* are secured by dividing the titration value in cc by the solubility value as determined by the temperature of the sample (see Table 8, Appendix).

For altitudes other than sea level, correction for barometric pressure must be made if precise results are desired This is done by determining the oxygen solubility value at the pressure involved by the use of the following formula:

$$s_1 = s\frac{p}{760} = s\frac{p_1}{29.92}$$

in which
s_1 = solubility at p or p_1
s = solubility at 760 mm or 29.92 in.
p = barometric pressure in millimeters
p_1 = barometric pressure in inches

For quick reference, Rawson's nomogram (1944) for obtaining oxygen saturation values at different pressures is useful (see Appendix, p. 366)

RIDEAL-STEWART MODIFICATION OF WINKLER METHOD

The Winkler method just described will often yield satisfactory results, but significant errors may occur if the water contains appreciable quantities of nitrites, iron salts, or certain organic compounds Under these circumstances the Rideal-Stewart modification of the Winkler method should be used Since in work on unknown waters it may be uncertain whether the Rideal-Stewart modification is necessary, it is common prac-

tice to use the latter as a regular procedure on all waters, the only disadvantage being the use of the additional steps in the analyses.

Reagents

(Reagents 1–5 are given under Winkler Method, p. 207.)

6. Potassium permanganate solution 6.32 g. $KMnO_4$ in distilled water, make up to 1 l.

7. Potassium oxalate. 2 g in 100 cc. distilled water (Since this solution may deteriorate rapidly, it should be made up frequently)

Procedure

1 Remove stopper from the 250-cc sample bottle containing the sample to be analyzed and by means of a long narrow volumetric pipet add exactly 0 7 cc of concentrated sulfuric acid (reagent 3, p 207) just below surface of water.

2. Then with a similar pipet add at once, and well below the surface, enough (usually 1 cc.) of the potassium permanganate solution (reagent 6) to yield a typical permanganate violet color which will remain permanent for at least 20 min. after the bottle has been mixed thoroughly by repeated inverting. If the permanganate color does not persist for 20 min., add a small amount of the permanganate solution, mix by inversions and let stand for suitable interval, continue the same procedure until the violet color persists for the 20-min interval

3 Add 0.5 cc of the potassium oxalate solution (reagent 7), replace the stopper and invert bottle several times, allow to stand for 5 min , if after this interval the color of permanganate persists, add another 0.5 cc of the potassium oxalate solution and mix as before.

4 After the permanganate color has disappeared completely, add 1 cc of manganous sulfate solution (reagent 1, p 207) and 3 cc of the alkaline-iodide solution (reagent 2, p 207), insert stopper and mix by repeated inversion of bottle. Allow the precipitate to settle about halfway in bottle, then mix again and let settle, allow sample to stand for at least 5 min

5. Then proceed as in the regular Winkler method using steps 3 and 4. The results are calculated as already described (p. 209).

General Considerations

a In field work, the analyses of the dissolved oxygen should be made immediately after the sample is secured and the reagents added (Winkler reagents 1–3, Rideal-Stewart modification reagents 3, 6, 7, 1–3) up to the point where storage and transportation to the laboratory is safe

b For dependable work it is necessary that the temperature of the water at each sampling position be measured.

c. If appreciable amounts of iron salts are present, the reduction of the color of the permanganate, even when the proper amounts of oxalate solution are added, may be very slow To remedy this condition, add 2 cc of potassium fluoride (40% solution) along with the permanganate and decolorize in the dark

d If it is necessary to determine the dissolved oxygen content of waters containing various kinds of industrial wastes, such as sugars, starches, paper-mill wastes, chlorinated wastes, and mine wastes, special correctives and procedures must be added to the methods described, directions for which are available in "Standard Methods for the Examination of Water and Sewage," 9th ed , 1946

MICRO-WINKLER METHODS

The limnologist is sometimes confronted with situations in which only small samples can be secured, or in which it may be preferable to use only small samples The standard Winkler method, or the Rideal-Stewart modification, can be adapted for the analyses of samples having a volume of less than the usual 250 cc. by using a sample having a volume representing some convenient divisor of 250 and by the use of the same divisor applied to the quantities of reagents used For example, if it is desired to determine the dissolved oxygen in a 25-cc sample, then the quantities of reagents used should be one-tenth of those of the standard method, the only exception being that of the sodium thiosulfate in which instance convenience and accuracy demand that it be considerably diluted to a known degree Samples as small as 10 cc and even 5 cc may be so analyzed Obviously, the pipets and burets used must be graduated finely enough to make possible the precision necessary to maintain the original accuracy of the standard Winkler method Addition of reagents may be satisfactorily accomplished by the use of microburets drawn to long capillary points In the final computation of results, proper allowance must be made for the dilution of the sodium thiosulfate. A dilution of 10 times the original volume is convenient and usually adequate although greater dilution can be used if necessary. Because of the small size of the sample it is advisable to make the final titration in a tall dish and by means of a buret graduated to 0 05 cc With adequately graduated glassware and with proper care of operation, results are obtainable which are as dependable as are those of the standard method

Of recent years various mechanical devices have been developed by means of which the micro-Winkler method is rendered more convenient and precise (Thompson and Miller, 1928, Fox and Wingfield, 1938, and others) With certain of these devices it is claimed that samples as small as 0 2 cc. can be analyzed Analysis of such small samples requires great care in all steps of the procedure.

COLORIMETRIC METHODS

Colorimetric methods for determining oxygen dissolved in water were devised more than 40 years ago Recently, improved methods have been developed some of which may come to have limnological value Among them should be mentioned those of Johnson and Whitney (1939) and Isaacs (1935). While these methods appear to have some promise for certain purposes, they cannot be regarded at this time as a substitute for the established ones described on earlier pages

OXYGEN DEFICIT

By oxygen deficit is meant that amount of dissolved oxygen necessary to raise the quantity already present at a selected depth to some chosen standard Two methods of computing oxygen deficits have come into use *Actual deficit* is the difference between the quantity of oxygen present at the selected depth and the amount necessary to saturate the water at that temperature which existed in the sample at the time when it was collected. *Absolute deficit* is the difference between the amount of oxygen present at the selected depth and that necessary to saturate the water at a temperature of 4° C (9 26 cc. per l, minus a correction for the elevation of the lake surface above sea level)

Actual deficit may be computed by means of the following formula

$$\frac{(O^{as} - O^{a}) + (O^{bs} - O^{b})}{2} = d^{ab}$$

$$d^{ab}V = D^{ab}$$

$$D^{ab} + D^{bc} + D^{cd} + D^{de} \text{————————} D^{xy} = \text{Total actual deficit}$$

in which

O^{as} = amount of dissolved oxygen which surface water of lake would have if saturated with oxygen at temperature prevailing at time of sampling

O^{a} = amount of dissolved oxygen actually present in sample of surface water

O^{bs} = amount of dissolved oxygen which lake water would have at first depth level in vertical sampling series if saturated with oxygen at temperature observed in sample

O^{b} = amount of dissolved oxygen actually present in sample of water from first depth level

d^{ab} = mean oxygen deficit in uppermost stratum of lake

V = volume of uppermost stratum of lake

D^{ab} = total actual oxygen deficit in uppermost stratum of lake

D^{bc}, D^{cd}, D^{de} = actual oxygen deficits in successive strata of lake

D^{xy} = actual oxygen deficit for final and lowermost stratum of lake

If O_2 is expressed in cc. per liter or in mg per liter, then V must be in terms of liters Since results so computed may involve very large numbers, it will be more convenient to express the final results in larger units, as for example, in kilograms or kiloliters

The quantity of oxygen necessary to saturate the water at the different temperatures can be taken from a table of saturation values Correction for barometric pressure may be made by the use of the formula

$$S^1 = S \frac{B}{760}$$

in which

S^1 = solubility of O_2 at the sampling station
S = solubility of O_2 at sea level (760 mm)
B = barometric pressure in millimeters

The data referred to in the general formula given above make possible the computation of (a) the total amount of oxygen present in the lake at the time of sampling, and (b) the actual total oxygen deficit

If the volume of the lake and that of its various strata are not known, less comprehensive measure of the actual O_2 deficit can be secured by merely using the vertical series of O_2 analyses made in the deepest region of the lake

Absolute deficit may be determined by the use of the general formula given above for *actual deficit* but modified by substituting the amount of O_2 necessary to saturate the water at a temperature of 4° C instead of that for the observed temperature at the level involved Correction for elevation is computed as described above, using 4° C as the standard Certain other methods of computing oxygen deficits have been proposed (Hutchinson, 1938). *Oxygen gradient* (Maucha, 1931) may be computed but the method is more complicated and adds little to the information secured by means of oxygen deficit determinations

Free Carbon Dioxide

Samples for analysis of free CO_2 in water should be collected in the same way and with all of the same precautions as those for dissolved oxygen (p 206) Since free CO_2 escapes from water so readily, it is highly desirable that the analysis be made immediately after the sample is secured

REAGENTS

1 Phenolphthalein indicator· Dissolve 5 g of high quality phenolphthalein in 1 l of 50 per cent alcohol, neutralize with $N/50$ sodium hydroxide (Prepare the 1 l. of 50 per cent alcohol by diluting 526 cc of 95 per cent grain alcohol to 1 l with boiled distilled water)

2. Sodium hydroxide $N/44$ solution. (Limnologists will probably prefer to have this standard solution made up in some properly equipped chemical laboratory, if not, detailed directions can be found in treatises on chemistry or on water analysis.)

Procedure

1. Pour sample into a Nessler tube until 100-cc. mark is reached In so doing, use every care that sample is not agitated If a Kemmerer sampler is used, insert delivery tube of sampler deep into Nessler tube and admit water quietly at bottom of tube

2 Add 10 drops of phenolphthalein indicator.

3. Add $N/44$ sodium hydroxide from buret, stirring gently during titration, until faint permanent pink color appears

The amount of free carbon dioxide, expressed in parts per million, is calculated by multiplying by 10 the number of cc. of $N/44$ sodium hydroxide used in the titration

General Considerations

Recently, Peters, Williams and Mitchell (1940) claim to have shown that in a titration method using phenolphthalein and 0 1 N sodium hydroxide a sizable error results if the end point used is the "permanent" pink, an error which is eliminated by using as the end point a "lingering pink" which flashes all through the liquid and lasts for but one or two seconds

ALKALINITY

Alkalinity in most natural waters is due to (a) normal carbonate, (b) bicarbonate, and (c) hydroxides. By the use of two indicators and a standard solution of a strong acid these three sources of alkalinity can be distinguished and their quantities measured

REAGENTS

1. Sulfuric acid, $N/50$ solution. (This solution must be made up according to standard specifications Limnologists will probably prefer to secure this solution from some chemical laboratory, if not, directions for the proper preparation of this solution will be found in standard works on chemistry or on water analysis.)

2 Phenolphthalein Prepare this solution according to same directions as given on p 213 for phenolphthalein indicator in determination of free carbon dioxide.

3 Methyl orange indicator. Dissolve 0 5 g of high quality methyl orange in 1 l of distilled water Keep in dark glass bottles

PROCEDURE FOR DETERMINING PHENOLPHTHALEIN ALKALINITY

1. Deliver 100 cc of sample into white porcelain casserole or into white porcelain evaporating dish, or into Erlenmeyer flask set on white background

2 Add 4 drops of phenolphthalein indicator If color appears in solution, hydroxide or normal carbonate is present

3. If sample becomes pink, add *N*/50 sulfuric acid from buret until pink color just disappears, record number of cubic centimeters of acid used.

The phenolphthalein alkalinity, expressed in parts per million of calcium carbonate, is equal to the number of cc. of the *N*/50 sulfuric acid used multiplied by 10.

PROCEDURE FOR DETERMINING METHYL ORANGE ALKALINITY

1. Prepare sample as described above in directions for determining phenolphthalein alkalinity, or, if desired, use sample to which phenolphthalein has been added.

2 Add 2 drops of methyl orange indicator to sample If yellow color is produced, hydroxide, normal carbonate, or bicarbonate is present

3 Add *N*/50 sulfuric acid from buret until color shows first change from pure yellow; end point is a faint orange tint, record number of cc. of acid used

The *methyl orange alkalinity*, expressed in parts per million of calcium carbonate, is equal to the total number of cc of *N*/50 sulfuric acid used multiplied by 10

INTERPRETATION AND CALCULATION OF RESULTS

It has become common practice to record results of alkalinity measurements as *p p m phenolphthalein alkalinity* or as *p p. m methyl orange alkalinity*, since from these concise statements various interpretations and

Result of Titration	*Alkalinities Expressed as P. P M of Calcium Carbonate*		
	Hydroxide	*Carbonate*	*Bicarbonate*
P = 0	0	0	T × 10
P < ½T	0	2P × 10	(T — 2P) × 10
P = ½T	0	2P × 10	0
P > ½T	(2 P — T) × 10	2 (T — P) × 10	0
P = T	T × 10	0	0

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calculations may be made when desired. Further differentiations of alkalinities due to hydroxide (OH), normal carbonate (CO_3) and bicarbonate (HCO_3) as made possible by the titrations indicated above are shown in the table on page 215 of the five possible conditions which may be met in results of measurements of phenolphthalein and methyl orange alkalinities. P = number of cc *N*/50 sulfuric acid used in titration with phenolphthalein, T = number of cc *N*/50 sulfuric acid used in total titration (phenolphthalein plus methyl orange)

GENERAL CONSIDERATIONS

a Greater precision in the use of the method is attained if the operator uses some means of judging the end point more accurately. Standards may be provided by using two standard buffer solutions one having a pH of 8 0 and another one having a pH value of 4 0 Phenolphthalein indicator is added to the first, methyl orange indicator to the other Each solution so prepared will give for the indicator used, the exact color tint to be watched for in the titration.

b If defective color vision interferes with the ability of an operator to use the method as outlined above, certain other indicators may be used as substitutes for phenolphthalein and methyl orange provided the substitute indicators have other colors and have turning points at pH 8.0 and pH 4 0 respectively If such a substitution is made the results are expressed in parts per million of calcium carbonate and as alkalinities using the substitute names.

Hydrogen-ion Concentration

A general discussion of fundamental aspects of hydrogen-ion concentration may be found in various treatises on that subject A brief account of the essential features occurs in the author's book, *Limnology* (1935, pp 108–116) Two methods of expressing hydrogen-ion concentration are in use, namely, (a) the number of moles of ionized hydrogen per liter, and (b) the pH scale, which may be defined as the "logarithm of the reciprocal of the normality of free hydrogen ions." Because of its convenience, the pH scale is now very generally used In this book hydrogen-ion concentration is expressed in the pH scale

The wide use of hydrogen-ion concentration measurements in various fields of science has led to the development of many different methods for making such determinations A great array of materials, indicators, standard colors, and instruments is now available on the market accompanied by detailed descriptions of construction and directions for use Consequently, it is scarcely worth while for the limnologist to go through the elaborate and tedious processes of making up his own standards or constructing his own apparatus, even if his laboratory is equipped for such

work Costs are such that ordinarily it is preferable to purchase suitable outfits from reliable manufacturers Because of the highly satisfactory directions which accompany modern hydrogen-ion concentration equipment, only a general discussion will be given here

Methods of measuring hydrogen-ion concentration are, in general, of two kinds (a) colorimetric and (b) electrometric. The procedures and equipment for the operation of both are numerous and varied Of these two general types, the electrometric method has greater precision.

SELECTION OF A METHOD

The selection of a method for measurement of hydrogen-ion concentration depends upon various circumstances prominent among which are (a) physical features of the water, (b) chemical features of the water, and (c) degree of accuracy required Owing to the fact that all methods have their own sources of error and their own limitations it is highly desirable that, if possible, every working laboratory should possess more than one kind of outfit in order that one may be checked against the other The choice of a method for a particular job will depend upon the nature of the waters involved Likewise, the degree of accuracy required will depend upon the use to which the data are to be put There is no profit in working for a much higher degree of precision than the occasion warrants and the intelligent worker will make the proper discrimination However, once the necessary degree of accuracy has been correctly ascertained, it is imperative that the method selected be conditioned and operated so that this accuracy is assured in the results In the final expression of results, all pertinent facts as to method, operation, and accuracy attained, should be recorded for future reference.

COLORIMETRIC METHODS

Colorimetric methods depend upon the addition of the proper sensitive indicator solution to the sample and a comparison of the color so produced with graded, colored standards the pH values of which are known

Color Charts

Sets of graded colors representing ranges of pH values are sometimes used as standards Such colors are usually printed on paper in some convenient form. When known to be in dependable condition, fair results may be obtained if all of the limitations and weaknesses of the method are known and the necessary precautions are observed However, about the only advantages such standards have over better ones are general convenience and low cost On most occasions more exact and more dependable standards, such as those mentioned later, will be chosen. The follow-

ing are among the principal weaknesses (a) instability of colors, (b) flat surface; (c) danger of damage by wetting.

General Considerations

a Color charts must be protected from exposure to light except when in actual use.

b Color charts must be checked frequently against some dependable set of standards.

c High precision cannot be expected from this method

d. Color charts may be reevaluated, if changes in color quality have occurred, by checking them against a suitable standard However, it is usually better to discard color charts which show appreciable change

e. Since colors on charts cannot be tested directly by potentiometrical methods, they are of necessity only secondary standards made by matching them as closely as possible against some basic standards

f One prominent source of error arises from the fact that when a liquid sample is compared with a color standard of an entirely different material the difference in color transmission may be considerable

Solution Standards

One of the most widely used forms of colorimeter, and in many respects the most satisfactory, is that in which the standards are contained in a series of uniform, hermetically sealed tubes of special nonsoluble clear glass, uniform in bore and thickness. Each tube contains a definite amount of a standardized buffer solution having the desired pH value, to which is added an amount of indicator solution suitable to portray the pH value of the buffer A preservative is added to prevent growth of mold. All operations are conducted under sterile conditions The solution is then checked electrometrically, and the tube sealed and labeled with the name of the indicator and the pH value. Such tubes present a graded series of colors each of which represents a particular pH value Such a series may extend throughout the whole pH range or any part of it and may have whatever pH intervals between tubes the operator desires. For ordinary purposes the interval used is 0.2 pH These solution standards have two important virtues, namely, (a) they can be checked electrometrically and are thus basic colorimetric standards, and (b) the standard is in all respects similar to the unknown to be tested since the latter is contained in the same kind of a tube, has the same quantity of liquid, and has received the same indicator solution

General Considerations

a Solution standards are not permanent Certain commercial companies guarantee colorimeters for one year against color change. Some colorimeters may remain in good condition much longer than one year.

However, they should be examined frequently, even from the date of original construction, and checked against other standards. Such checks must include every tube in the set since some tubes may change faster than others.

b. Tubes which have undergone change in color may be reevaluated by careful comparison with other standards, if most of the color is still present. However, reevaluated tubes must be checked very frequently. If much color change has occurred, a new set is recommended.

c. When not in use, color tubes should be kept in the dark.

d. Color tubes should not be exposed to excessive heat.

e. In the past, some workers have made use of temporary solution color tubes made up rapidly with buffer solution and indicators in test tubes closed with stoppers. Such colorimeters are less expensive but have very limited life; color changes occur very quickly, and a new colorimeter must be made up at least every few days. Ordinarily, such colorimeters are not to be recommended.

f. Solution color tubes should be dated when first received. Some companies date their tubes when they are made.

Colored-glass Standards

Colorimeters are now available in which the standards are in the form of glass units whose colors represent the various pH values in a graded series. The glass standards may be of various forms. A common form is one in which colored glass disks are mounted in circular holders of convenient dimensions. Makers usually claim that such color standards are permanent and that each color has been carefully checked electrometrically. It must be understood, however, that such checking is of necessity indirect and can be made only by comparing the color in the glass with a liquid standard which has been checked electrometrically. In this respect these glass standards resemble color charts mentioned previously. Permanence of color and convenience are prominent virtues of glass standards, but like color charts they present the problem of comparing accurately the liquid sample containing an indicator with a colored standard composed of an entirely different material.

General Considerations

a. Glass standards must be thoroughly clean before being put into use. Since some color disks are composed of several layers of glass sealed together, any cleaner which will attack the sealing materials must be avoided.

b. If dropped on a hard surface, damage to glass standards may occur either as breakage or as a shattering of the sealing materials.

c. It is necessary to have definite information from the maker as to the suitability of a glass-standard colorimeter for use in either daylight or in

artificial light; also concerning any accessories necessary to insure as accurate results as possible.

Comparators

Devices known as comparators are commonly used in connection with colorimeters as means of increasing the accuracy and dependability of readings. These aids to operation vary from the simple "block" comparators to elaborate electrical devices equipped with artificial lights and glass screens. Certain comparators and lamps make possible dependable readings at night or in places where ordinary daylight is variable and uncertain. Properly chosen comparators are desirable for many kinds of colorimetric work and, in some instances, higher precision and constancy of reading values can be attained only through them. Ordinarily the worker will do well to follow the advice of the manufacturers in the selection of a comparator for his particular kinds of work.

pH Test Papers

Test papers, prepared from standardized pH indicators, are now available. These sensitive test papers are useful only in the *approximate* estimation of the pH of solutions and for such purposes may sometimes be useful. However, their limitations must be known and their use governed accordingly.

Indicators

Colorimetric measures of pH depend upon the use of dyes which manifest a definite but different color for each particular pH value of the medium into which they are introduced. These differences in color of the indicators is an expression of the differences in hydrogen-ion concentration. Color change by an indicator extends over a certain range of change of pH in the medium, therefore, each indicator has a certain definite pH range beyond which, in either direction, color change is no longer usable. This means that indicators must be chosen which are suitable for the pH range of the samples. There are many different indicators on the market from which the worker will choose those most appropriate for his needs. The following selected list includes indicators serviceable for ordinary purposes.

Indicator	pH Range	Color Change
Bromphenol blue	3.0–4.6	yellow-blue
Bromcresol green	4.0–5.6	yellow-blue
Chlorphenol red	5.2–6.8	yellow-red
Bromthymol blue	6.0–7.6	yellow-blue
Phenol red	6.8–8.4	yellow-red
Thymol blue	8.0–9.6	yellow-blue

Wide-range indicators, sometimes called universal indicators, have a range of color change which is spread over most of the pH scale For example, certain wide range indicators are claimed to have a pH range of 1.2 to 11 0 These indicators are most serviceable in the preliminary testing of an unknown where the approximate results secured are useful in the subsequent selection of a proper specific indicator for determining the pH value with greater accuracy Ordinarily these indicators are not used for final results unless only a very rough estimation is sufficient

Indicators may be secured either in crystalline form or as indicator solutions so prepared that they are available for use at once Ordinarily, the limnologist will find it convenient and an economy of time to use the indicator solutions already prepared by a reliable supply company If made up from the crystalline form, great care must be taken to follow rigidly the instructions for the preparation of solutions as given by the firm supplying them.

Indicator solutions should be stored in the dark and securely protected from dust or any form of contamination

Suitability of Colorimetric Methods

Under ordinary conditions it may be expected that the better colorimetric methods will give reliable results when used properly on the clearer, cleaner, unmodified inland waters However, they are uncertain for highly colored bog waters, highly turbid waters, and contaminated waters. Any materials in the sample which obscure the color reaction of indicators or which by chemical action alter the nature of the indicator make a colorimetric method subject to errors In general the colorimetric method is known to be subject to the following kinds salt errors, protein errors, acid errors, temperature errors, off-color errors, oxidation/reduction errors and colloidal errors (Perley, 1937) While in many of the unmodified inland waters of the cleaner, purer types some of these errors may not be particularly significant, it behooves the limnologist to be on his guard in applying colorimetric methods, especially to bog waters, salt waters, contaminated waters, and various other less common types having unusual chemical and thermal features It must be remembered that rise in temperature alone generally produces an increase in ionization Far too often measurements are made without any effort or provision for checking the reliability of the colorimeter for the particular water concerned This is unsafe practice and it does not clear the case to assume that the error will necessarily remain the same in the same water Many waters are subject to wide and significant variations

ELECTROMETRIC METHODS

Electrometric outfits are of several types of which the following are prominent at present those using a hydrogen gas electrode, a quinhydrone

electrode, an antimony electrode, or a glass electrode Portable outfits are now available and usually meet the needs of limnologists in a satisfactory way Such outfits are very diverse in construction although the fundamental features of operation may be similar In addition to the advantage of possessing a greater precision than colorimetric methods, the electrometric methods are suitable for a much wider range of different types of water, functioning well in colored waters, highly turbid waters, and contaminated waters Makers of electrometric outfits supply full information concerning the construction and operation of their instruments Since the various outfits often require different procedures, no attempt will be made here to outline them For work in the field, outfits with special glass parts are subject to breakage and in that respect may be less preferable than others which use little glass and that easily replaceable

The table on page 223 indicates some of the features of electrometric outfits which employ one of the four principal types of electrodes

RESERVE pH

Reserve pH, indicated by the symbol RpH, is that value secured by a second pH determination made after the sample has been thoroughly aerated Aeration of the sample may or may not result in a value (RpH) different from the initial pH, if the total pH results from the presence of substances in the water not releasable by aeration, then the initial pH value and the RpH value will be the same, if, on the other hand, the total pH is in part due to substances in the water releasable by aeration, then the RpH value will differ from the initial pH Free CO_2 in the sample will be partly responsible for the initial pH reading, aeration will cause the release of the free CO_2 and the postaeration measurement will show an RpH value which is higher on the alkaline side of the scale

ELECTROLYTES

Pure water is a poor conductor of electricity Acids, bases, and salts in solution in water produce solutions which are relatively good conductors of electricity Such substances are called *electrolytes* Since acids, bases, and salts differ in their solubility in water, they differ in their conductance of electricity, those with slight solubility being *weak electrolytes,* while those with high solubility are *strong electrolytes* Therefore, a measure of the total electrolytes in natural waters can be secured by measuring the electrical conductance of a sample of the water Such a measurement provides a means for studying the nature of a solution Since it is claimed that, other things being equal, the richer a body of water in electrolytes, the greater the biological productivity, any measurement of the electrolyte content of water is of considerable importance in limnological practice.

SHOWING SELECTED SERIES OF CHARACTERISTICS OF DIFFERENT TYPES OF ELECTRODES USED IN pH MEASUREMENTS*

	Hydrogen Gas Electrode	*Quinhydrone Electrode*	*Antimony Electrode*	*Glass Electrode*
Salt Errors	None	In salt concentration above 1 molar	Considerable magnitude	In presence of sodium salts at ranges above pH 9.5
Limit of Error	pH 0.01	0.02 below pH 8.5	pH 0.1	pH 0.03
Range	pH 0.0–14.0	pH 0.0–8.5	pH 0.0–14.0	pH 0.0–14.0
For Turbid or Colored Waters	Suitable	Suitable	Suitable	Suitable
Special Electrode Surface	Required	Not required	Not required	Not required
Addition of Auxiliary Material	Not required	Required	Not required	Not required
Affected by Presence of Dissolved Gases	Yes	No	Yes	No
Oxidation/Reduction Systems	Cause errors	No errors in solutions of mild oxidizing or reducing intensity	Cause errors	Independent of oxidizing and reducing solutions
For Continuous Measurements	Not easily adaptable	Not adaptable	Usable	Usable
Resistance System	Low	Low	Low	High
Other Characteristics	Not suitable for unbuffered solutions over range pH 5.0–8.5	Not dependable in low buffered solutions above pH 5.0	Calibration different for still and moving solutions	Suitable for unbuffered solutions

*Based upon a summary by Perley, 1937

In methods for measuring electrolytic conductivity, *resistance* is determined by an appropriate instrument *Conductance* is the reciprocal of the resistance involved. The unit of measure of conductance is the *reciprocal ohm* to which has been given the name *mho* Some instruments are also so constructed as to read directly in *reciprocal megohms* Both resistance and conductance depend upon the size and shape of the sample and are therefore not specific properties of a substance. When a resistance value is made to correspond to a sample of centimeter cube dimensions it is designated as *specific resistance;* likewise, when a conductance value is so treated it is designated as *specific conductance* or as *conductivity*

EQUIPMENT

Rarely if ever will the limnologist find it practicable to construct the necessary equipment for conductivity measurement. For work in a laboratory supplied with electrical current, the operator will find on the market various outfits suitable for his purposes and it will be decidedly to his advantage to purchase such equipment from some reliable manufacturer who will supply full information as to the construction and operation of the outfit Since it is often necessary to make conductivity tests in the field or

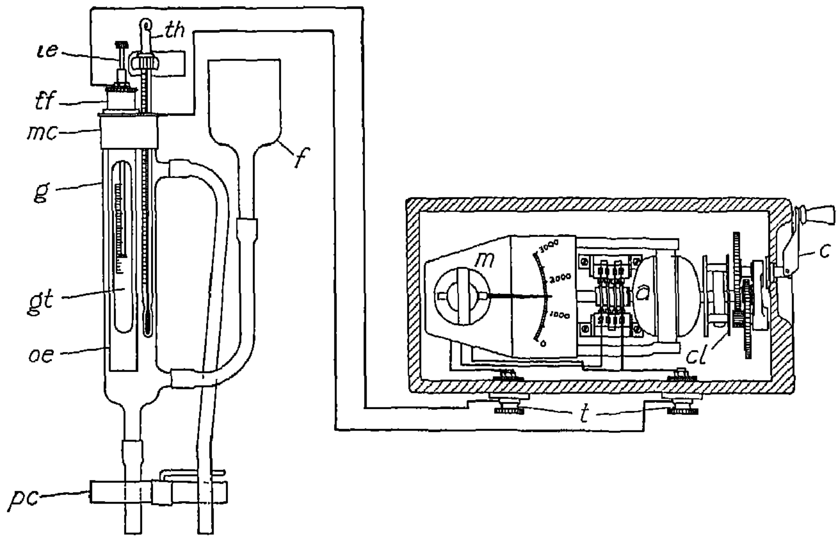


FIG 63 Diagram of construction of Dionic Water Tester Unit on the left is the conductivity tube, that on the right is the conductivity meter (*a*) Armature, (*c*) Crank (*cl*) Constant speed clutch (*f*) Funnel (*g*) Glass container (*gt*) Glass tube, (*ie*) Inner electrode (*m*) Conductivity meter and scale (*mc*) Metal cap, (*oe*) Outer electrode, (*pc*) Pinch cock (*t*) Terminals for connection to meter, (*tf*) Top fitting (*th*) Thermometer (Redrawn from Evershed and Vignoles, London, England, with permission)

in temporary field quarters not equipped with electric current, a self-contained portable outfit is a necessity An excellent instrument of this type is the Dionic Water Tester made by Evershed & Vignoles, London, in which a complete generator-indicator unit in very compact form is a special feature Fig. 63 shows the principal features of construction and assembly. Since it is probably the most satisfactory self-contained portable outfit yet devised the following procedure is based upon its use.

Procedure for Dionic Water Tester

1. Set up instrument in some protected place and on very stable table, make certain that conductivity tube is firmly mounted on some fixed vertical support near edge of table, arrange overflow and outlet tubes to discharge into suitable container below, place conductivity meter alongside conductivity tube and connect them together, attaching insulated wire leads to proper binding posts

2 Make certain that conductivity tube is scrupulously clean, open outlet tube temporarily to allow escape of any liquid from previous test, close pinch cock on outlet tube and fill glass tube through funnel with liquid to be tested, drain out and repeat to make certain that all traces of any previous test have been removed

3 Remove thermometer from storage case and pass it through hole in top fitting so that most of its length is within glass test chamber, immobilize it in that position.

4. Fill glass tube with liquid to be tested until excess runs out through overflow tube, insuring that proper quantity is provided

5 Record temperature of liquid as indicated by thermometer, adjust inner electrode so that its lower edge is opposite mark on scale corresponding to recorded temperature

6 Turn crank of generator clockwise at a speed above that at which clutch is felt to slip (usually about 120 r. p m), as soon as pointer of conductivity meter is at rest, take reading Reading is in units desired, no computation necessary. Record temperature and conductivity reading.

7 If desirable, repeat test on same sample, making certain that any necessary readjustment for temperature is made

8 Drain out sample and thoroughly flush out all parts with distilled water, if further testing is postponed, put large cotton plug in funnel and close entire conductivity tube in its box

General Considerations

a The temperature compensating scale in the conductivity tube has a range of 10° to 40° C., therefore water to be tested must be warmed or cooled if outside these limits.

b. Occasionally the operator should test his apparatus for possible

current leakage between the lead wires connecting to the conductivity tube, or across the tube itself, by proceeding as if making a conductivity test but with no water in the tube. Under these conditions the meter reading should be zero, if not, there is current leakage which must be removed before further tests are made.

c. Pure rubber tubing only should be used for connections since vulcanized rubber contaminates the sample

d. Under ordinary conditions the effects of barometric or hydrostatic pressure are negligible.

e. In making a test, care must be taken to avoid trapping air under the inner electrode when filling the tube with liquid. Escape of such air is facilitated by four small holes which pierce the electrode disk However, if air still tends to become pocketed there, it can be removed by manipulating the electrode stem.

f Scales of different ranges may be secured for the conductivity meter but for natural uncontaminated inland waters a scale of 0 to 5000 will be preferable

g After the apparatus is set up, the time of making a test need not exceed two or three minutes.

h. Since the apparatus is very sensitive to exceedingly small amounts of electrolytes in solution, every care must be taken to keep the inside surfaces of all parts concerned scrupulously clean at all times

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(For Chapter 14)

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Part IV

Biological Methods

PLANKTON METHODS

Collecting Apparatus

In many plankton methods two processes are involved (a) collection of a sample of some natural, plankton-producing water and its transportation to the surface, and (b) removal of plankton from this water Both may be performed separately or simultaneously, depending upon the kind of equipment used.

SAMPLERS AND SAMPLING DEVICES

Kemmerer Water Sampler. The modified Kemmerer sampler, described on pp 199–201, provides trustworthy plankton samples With it water can be taken from a positively known depth and transported to the surface unaltered Small capacity of the sampler may be regarded as a disadvantage since the required number of trips to the same depth in order to secure a usable volume of water slows up the work, but, on the other hand, the increased number of trips may add to the efficiency of sampling as a whole So far as is known, motile plankters do not escape from this sampler Large-size samplers (3-l capacity or more) are often convenient in plankton sampling.

Ricker (1938) and others claim that certain plankters, notably *Daphnia*, are able, in the upper water, to see a collecting device (plankton trap, plankton net) and avoid it by day, thus causing a certain loss. To what degree such loss occurs when a Kemmerer sampler is used is yet unknown, but it would seem that because of its shape, size and method of use, error from this source, if present at all, should be minimal.

Pump and Hose Method The pump and hose method, already discussed on pp 201–202, has all the disadvantages described there in sampling for plankton. The uncertainty as to the exact level from which water comes is in itself serious enough to ban its use for many purposes However, another serious defect arises when sampling for plankton, namely, the loss of a certain portion of the plankton Crustacea due to current reaction. Some Copepoda (*Cyclops*, *Diaptomus*, and others) manifest avoiding reactions in water moving toward the intake end of the hose and, as a consequence, 10 per cent or more of such plankters may be lost in the process of sampling It has been claimed that this loss of plankton Crustacea, due to rheotactic reaction, may be reduced by installing a funnel,

with sides making an angle of 30°–40° with the vertical, in the intake end of the hose, the effect being to enlarge the intake area and reduce the velocity of flowage Because of its various disadvantages, the pump and hose method is now largely abandoned, particularly for quantitative work. For occasional, and perhaps some special kinds of qualitative work it may have some value, particularly because of its delivery of large quantities of water in a relatively short time Gear pumps produce fragmentation of plankters and must be avoided if the organisms are to be secured intact

Water Bottles and Similar Devices Certain sampling devices, often referred to as "water bottles," are sometimes used in plankton work Hale's water bottle, described on pp 202–204, belongs in this class, also various types of large bottles so harnessed that they can be sent to various depths on a rope, the stopper jerked out and the bottle allowed to fill Various accessory devices attached to such bottles improve their performance and speed up sampling Such bottles fall short, in one way or another, in meeting the requirements of good plankton sampling They fill by inflowing water thus setting up streaming and automatically leading to losses of certain motile plankters by avoiding reaction, as in the instance of the pump and hose method For plankton work such water bottles should be looked upon largely as emergency or improvised devices to be used only for certain rough operations

Other Samplers Innumerable samplers have been designed, some of which are merely modifications of certain fundamental types Many samplers, constructed for other purposes, are of only incidental or highly specialized use in plankton work Certainty in collection of an unmodified sample at a definitely known position is a consideration of prime importance in the choice of a sampler and any device which even in the slightest way falls short of this test should be avoided. Convenience may well be considered but must not be put first in the qualifications of a sampler.

PLANKTON NETS

Some portion of the plankton may be collected by any fine-mesh cloth which will allow water to pass through it However, for various reasons, certain materials are superior and, except in emergencies, those known to be particularly suitable should be used. It must be understood, however, that irrespective of fineness of mesh or its construction, no material which by any reasonable interpretation might be called a *net* will remove all plankton from a sample Plankton separated from water by means of a net is generally referred to as *net plankton* and represents only a fraction of the total population

Silk Bolting Cloth Silk bolting cloth is generally regarded as the best material for plankton nets It is commonly manufactured in six dif-

ferent grades and in a large range of sizes of mesh (see Appendix, Tables 9 and 12). It is sometimes possible to secure, in the *standard* grade, a size even finer than No. 25 but it is doubtful whether in most kinds of net-plankton work the additional cost and the slower operation are justified. In the grades listed in Table 9 the *standard* is the lightest grade and the thickness and strength of threads increase in the order of mention, XXX grit gauze being the heavy-duty grade suitable for the severe kinds of work. Some manufacturers stamp the name or the grade and size of mesh on the silk prominently. Unfortunately these marks soon become obliterated on a plankton net. Other makers weave colored threads into the selvages according to some code which expresses the grade, but not the size of mesh, of the material, but since the selvages are not always included on a plankton net they are of little service. The careful limnologist will enter on the cloth where it will not be lost a record indicating the grade, size of mesh, date of purchase, and the maker. These entries can be made with Higgins Waterproof ink or Higgins Eternal ink in some abbreviated way or in some code form which will occupy little space and in no way interfere with the functioning of the silk.

Shrinking of Silk Bolting Cloth. When new silk bolting cloth is first put into water a certain shrinkage occurs, the extent of which depends upon circumstances. Subsequent submergences in cool water may result in further shrinkage although eventually an approximate stability will be reached. Total expected shrinkage cannot be stated in fixed amounts. Published figures indicate a change of as much as 20 per cent in the size of apertures. Therefore it is commonly recommended that new silk bolting cloth be thoroughly shrunk before it is used for precise quantitative work. Shrinking may be done before the silk is cut out and installed in the metal parts of the net, by repeatedly wetting it with a wet sponge and pressing it with an iron just warm enough to accomplish the smoothing. Care should be taken to avoid the use of irons which are *hot* since high temperatures are detrimental to silk. Certain older, published methods which involve boiling are too severe. New unshrunken silk may be built into a net and the shrinking done by repeated submersion and drying if care is taken that the proper allowance is made in advance for subsequent change. If such allowance is not made the silk will become strained, especially in the windows of the bucket, if a bucket is used, and about the fittings on the metal supports, also in a single-seam net the shrinkage is likely to be less on one side thus resulting in a net which does not hang straight.

Linen. For some purposes certain grades of linen may be used for making plankton nets of the general utility type in which uniformity and fine size of mesh are not major considerations. A material sometimes known as India linen is often thus used. Any good grade of thin linen, not too tightly woven, may be suitable. It must be understood, however, that

such materials are in no sense a substitute for silk bolting cloth for precise work

WIRE CLOTH. Wire cloths, made in very precise form and in various sizes of mesh and diameter of wire, are available on the market Some of them have meshes which approximate those of the fine-mesh silk bolting cloth These wire cloths are made primarily for certain commercial purposes and manufacturers supply detailed information concerning them Usually it is not practicable to use them in plankton nets of the ordinary type. However, when made into forms convenient for plankton work, they may be used to collect the larger plankters from water, especially if means are devised for removing the catch from the screen

Installing Silk Bolting Cloth in Plankton Nets

Since the form of most plankton nets is that of a truncated cone, the preparation of silk bolting cloth for installation in them is facilitated by the use of patterns. In replacement of worn-out silk, new material may be cut to the proper shape by using the old silk, carefully removed from the metal parts, as a pattern, provided that the new silk has been shrunk in advance and that the old silk was originally in satisfactory form The use of the old silk as a pattern will often be made easier if it is first dampened and then smoothed out carefully with a hot iron However, it is often preferable, and sometimes necessary, to work with a paper pattern prepared as follows Measure radius (R) of brass ring at top of net (Fig 64),

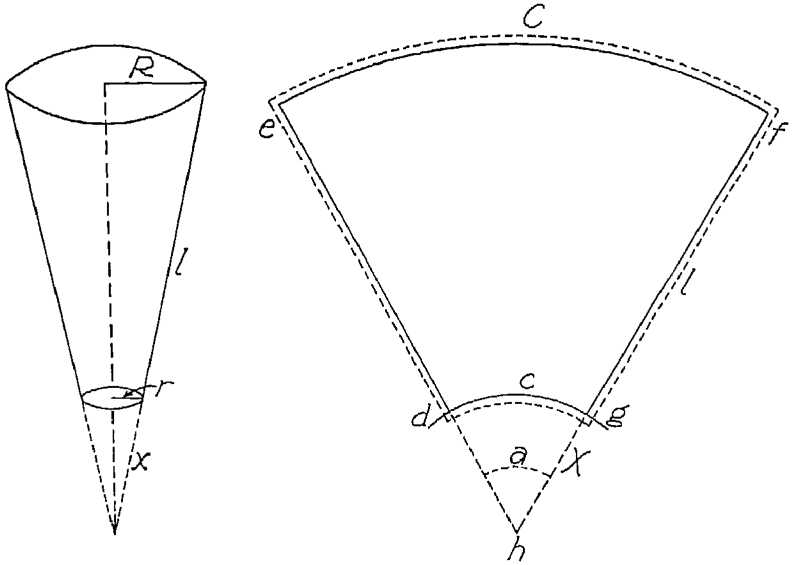


FIG 64 Diagrams illustrating method of preparing pattern for cutting out new silk bolting cloth for plankton nets.

measure radius r of brass headpiece of bucket, also determine desired length l of side of net. Using these dimensions, convert truncated cone into complete cone by prolonging sides to intersection, determine length of x by use of the formula

$$x = \frac{rl}{R - r}$$

Then x plus l gives length of radius of circle a certain arc of which represents shape and length of upper part of net C Determine angle a by means of formula $a = \frac{360\ r}{x}$.

Using l plus x as radius, lay off arc C of larger circle on smooth piece of paper. At center h of arc so constructed, lay off angle a by means of protractor and draw lines he and hf Then with x as radius, draw arc c of smaller circle so that it cuts across lines he and hf

The pattern is now complete It consists of the area $gdef$ and represents the surface of the desired truncated cone unrolled and spread out in one plane However, allowance must be made for seams, the character of which depends upon the structural detail of the net being made. For standard plankton nets with detachable buckets, an allowance of about 1 cm. all around the pattern will usually be adequate (see dotted outline in figure to right, Fig 64)

The pattern should now be cut out carefully, fastened together temporarily and fitted onto the metal parts as a check on its correctness. If found correct, the pattern is then superimposed upon the silk bolting cloth on a smooth surface, and the margins are carefully marked on the silk with a soft pencil Under no circumstance should the pattern be pinned to the silk. The silk is then cut out with sharp scissors

The two long edges of the bolting cloth are sewed together, using a French seam Silk thread and as small a needle as possible should be employed A light coat of rubber cement applied along the line of stitches will effectively close all needle holes If the net to be filled is equipped with an upper canvas section, supported by the brass wire frame (truncated cone form), the silk bolting cloth should be sewed to the canvas as follows Turn bolting cloth inside out and pass up through larger end of canvas, small end first, until lower edge (larger end of sleeve) of bolting cloth is even with lower edge of canvas, sew two edges (bolting cloth and canvas) together; then turn bolting cloth right side out The French seam should be on the outside of the bolting-cloth sleeve when the latter is in correct position.

The lower end of the bolting-cloth sleeve must fit smoothly onto the headpiece of the bucket. If the silk sleeve is oversize, wrinkles will develop when the net clamp is screwed on, resulting in leaks. If slightly undersize,

the sleeve may be made to fit by longitudinally slitting the edge of the silk for a very short distance. If a bucket is not used on the free end of the net, the form of termination will depend upon the kind of receptacle employed.

The method of installation of bolting cloth in the detachable bucket which is commonly a part of standard plankton nets will depend somewhat upon the construction of the metal parts In case of replacement, the old bolting cloth may be carefully removed and used as a pattern, proper allowance being made at all points for subsequent shrinkage of the new silk The new silk, when installed, should show considerable slack in all directions in each of the windows, otherwise use may bring about further shrinkage, causing it to become taut and strained Slack in the windows, unless excessive, is a matter of no concern, usually it is evidence that the bolting cloth has not been strained by improper installation. New cloth should be cut a little wider than the height of the bucket in order that a small amount of free edge project beyond the upper and lower clamps. It must be long enough to provide the slack mentioned above, also to allow an overlap on one of the strips between the windows Since screws holding binding strips between windows must pass through the bolting cloth, it is necessary to provide the holes by burning them at proper places with a hot wire

Birge Cone Net

The Birge cone net (Fig. 65) has three main parts, a cone-shaped top piece, a middle straining section, and a bottom piece.

The top piece consists of a base *tp* of sheet copper 2 5 cm wide in the form of a cylinder having a diameter of 8 cm, the lowermost edge of which is bent outward and fits closely around a brass wire ring *r*, a cone of brass wire netting *nc* with 3-mm mesh, soldered to the upper margin of the base and having a side length of about 9 cm., a piece of brass wire *bw*, diameter about 2 mm, in the form of the letter V, fitted closely to the inside surface of the cone, the two ends soldered firmly to the inside surface of the copper base, and the opposite, apex end projecting beyond the cone and twisted into a loop for attachment of the main draw cord, and two small loops *l*, 180° apart, soldered to the outside surface of the base

The middle straining section is composed of a sleeve *s* of silk bolting cloth, India linen, or any other material, in the form of a truncated cone fastened to the top piece by being tied or sewed above the ring, also fastened to the upper part of the bottom piece in the same manner A strong cord *c*, which extends from each eye on the top piece to a similar eye on the side of the bottom part, is slightly shorter than the straining sleeve in order to take the weight or pull off the latter A band of heavier

cloth at the top and at the bottom of the straining sleeve provides a stronger attachment at those points. Supporting cords may hang freely on the outside as shown in Fig 65, or they may be enclosed in tunnels formed by two extra seams along the side of the net If the straining sleeve is of some very strong material, the side supporting cords may be omitted, provided the tie-on at top and bottom are secure.

The bottom piece is composed of a brass or copper tube *bp* about 4 cm long and 3 cm in diameter, a ring of wire *wr* soldered on the outside surface at the top edge, two loops or eyes, one opposite the other, soldered to the side of the tube for the attachment of supporting cords, and a threaded region on the bottom of the copper tube for the attachment of the receiving cup

The bottom receiving cup *b* may be in any convenient form which serves the purpose, but should be made of metal and the lowermost piece should screw on snugly to avoid loss. If a screw top from a kerosene can or some similar article of about the same weight is used, it will be necessary to solder a lead weight of appropriate size to the screw cap to insure prompt sinking of the net, otherwise the lower portion when wet may pocket air and tend to float

All metal parts may be made of galvanized iron, although copper or brass is preferable.

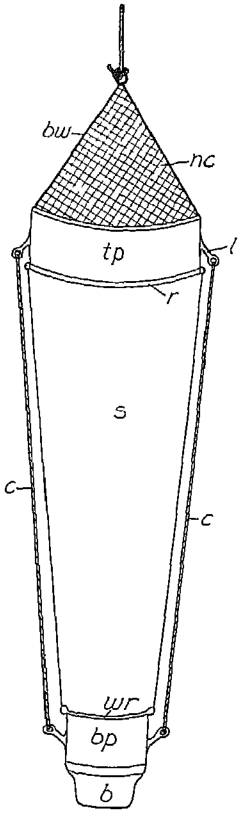


FIG 65. Birge cone net. (*b*) Detachable bucket or cup (*bp*) Bottom piece. (*bw*) Brass wire support (*c*) Supporting cord. (*l*) Loop for attachment of cord (*nc*) Wire-mesh cone. (*r*) Metal ring on top piece (*s*) Sleeve of bolting cloth, grit cloth, India linen, or other material. (*tp*) Top piece (*wr*) Wire ring on top of bottom piece

Other Tow Nets

Tow nets can be made in many different forms The following are useful.

A simplified and less expensive tow net may be made, using the same form and general dimensions as those given above for the Birge cone net

The top piece consists of a brass ring about 1 cm in diameter around which is sewed a complete, close fitting cover of strong braid. The cone, composed of some good grade, twisted-cord netting, is sewed firmly into braid around the ring and converges to the apex, ending in a brass ring which serves as attachment for the draw cord Three equidistant strips of braid, sewed firmly to the braid about the large ring, extend to the draw-cord ring, also a similar strip of braid extends from one ring to the other, interwoven along the longitudinal seam of the cone The other parts of the net are essentially the same as the Birge cone net, except that the bottom receiving cup may be in any convenient form from the screw-cup type to as simple an arrangement as a homeopathic vial or a test tube tied temporarily into place in the end of the net sleeve

A *larger type* of tow net also resembles the Birge cone net in general form. The top piece is composed of a tube of sheet brass or galvanized sheet metal, 12 cm. long and 11 cm. in diameter, one edge of which is bent around a wire ring. A second ring is soldered around the outside surface of the tube about 1 cm above the ring in the edge, thus providing a channel for the attachment of the straining net. At the other edge of the tube there is firmly soldered to the inside surface a heavy metal-screen cone, 15 cm long and with 7-mm. mesh, in the apex of which is firmly soldered a ring or loop for the draw cord. In this top piece the heavy materials used make unnecessary any wire supports The net is about 35 cm. long. Its larger end is double thickness of material to provide strength and is tied into place with strong cord in the channel between the two parallel rings The bottom receiving cup may be any convenient type. Lateral supporting cords for the net may or may not be needed depending upon the character and strength of the net material

A very simple tow net may be made in any convenient size by hanging a cone of India linen or of silk bolting cloth to a brass ring supported by three cords, equidistantly spaced and tied to the ring, which converge and join at point of meeting with the draw cord. To the top of the net is sewed a double strip of stout linen or some similar material, cut bias, and with a heavy cord sewed into the tunnel formed in its upper edge. This net, so prepared, is sewed to the ring by overcast stitches which pass over the ring and below the cord in the edge of the net Since the bottom of the net is closed, the catch must be removed by turning the net inside out and washing, with an up-and-down motion, the lowermost part in a bottle of water If desired, the tip may be cut off and a bottle or similar container tied into place

All tow nets must be weighted in order to insure sinking. Those using some form of metal collecting cup at the lower end can be weighted by the attachment of metal to it Tow nets which end blindly must be weighted by tying a sinker to the ring at the open end.

The pattern for cutting out the material used in the straining sleeve can be made in accordance with directions given on p 234 A simpler, but less exact, method of cutting out materials for the straining sleeve in plankton nets, particularly tow nets, is as follows On a large sheet of plain smooth paper, measure off along one edge a distance equal to circumference of top (largest) ring to which net material is to be attached Add about 1 5 cm to provide for seam Lay off from same corner, along edge at right angle to first, the distance equal to desired length of straining sleeve Through each of two distance points so located, draw line at right angle to edge and parallel to other edge. Cut smoothly along these lines, thus eliminating excess paper Fold paper lengthwise from right to left, bringing corners and edges exactly together, and press down fold. Then draw straight line from lower right corner to upper left corner (hypotenuse) With radius equal to length of paper and with center at lower right corner, draw an arc from upper right corner to intersection with diagonal line (hypotenuse). With scissors, make cut full length of hypotenuse and also cut around arc The pattern so produced will represent the form of the desired net. With the paper pattern make a trial wrapping about the supporting ring to check for accuracy If the trial shows the pattern to be correct, lay pattern out smoothly upon the fabric to be used and mark margins in pencil, remove pattern and cut out carefully. Under no circumstance pin pattern to fabric. Sew long edges together using French seam. A net so made is closed at the apex. If, however, some form of receiving cup is desired, the apex may be cut off as follows. By rolling upper edge of receiving cup across pattern above apex, locate position where width of pattern equals one-half circumference of cup; mark this level on folded edge of pattern, with distance from apex to mark as a radius, strike off arc from one edge to other, cut off by following arc.

TYPES OF PLANKTON NETS Plankton nets may be of various forms, depending upon their purposes and the preferences of the operator. Certain types of construction have general advantages.

THE WISCONSIN PLANKTON NET Many years ago Birge and Juday devised a net, sometimes referred to as the "Wisconsin net," which is now widely used. There are two sizes the "small net" and the "large net."

The *small net* (Fig. 66) consists essentially of three parts, an upper section in the form of a short inverted truncated cone, a middle section in form of an elongated truncated cone, and a detachable plankton bucket

The upper section is composed of previously shrunken, light- or medium-weight canvas, supported on a framework of 4-mm brass spring wire The upper ring of this framework has a diameter of 12 cm, the lower ring a diameter of 18 cm. These rings are connected to each other by three pieces of straight brass wire of smaller diameter. Loops at the ends of the connecting wires make union with figure-eight pieces of

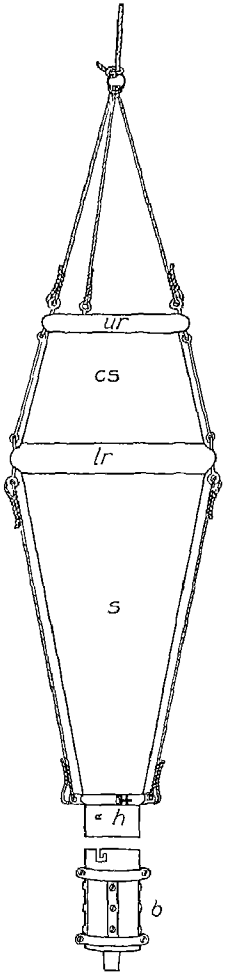


FIG 66 The Wisconsin plankton net (*b*) Detachable bucket, shown detached from headpiece (*cs*) Canvas sleeve between upper and lower rings (*lr*) Lower ring (*h*) Headpiece (*s*) Sleeve of silk bolting cloth between lower ring and headpiece (*ur*) Upper ring. The third supporting cord, extending from lower ring to headpiece, and the third supporting wire connecting upper and lower ring, are not shown in the figure.

similar wire, 3 strung on the upper ring and 3 on the lower, the pieces of both sets being equally spaced at intervals of one-third the circumference and held loosely in place by bits of small brass wire soldered to the ring on either side. On the upper ring, one end of the wire holding each figure-eight piece in place is soldered around the ring, then bent upward into a loop and brought down onto the other side of the figure-eight piece and again soldered around the ring These three loops serve as means of attachment for the draw lines All loops and eyes are oversize, thus forming loose joints, which provision makes this part of the net collapsible The canvas filling this upper section should be shrunk, then cut out, using a pattern made by the use of the formula given on p 235 Proper allowance must be made for extra length both at the top and bottom to provide for attachment to the rings The two cut edges of the canvas should be sewed together with strong thread to form a French seam, then the upper end is put through the inside of the upper ring, the edge turned outward over the ring and sewed below it The larger end of the canvas is put inside of and against the lower ring with the edge projecting past the ring for a distance of about 1 5 cm , a piece of strong braid, cut to fit the outside of the lower ring, fastens the canvas to the ring when stitched to it both above and below the ring The three draw cords converge at a convenient distance above the upper ring and are tied into a loop or a ring to which is fastened the main pull line.

The middle section is an elongated truncated cone of silk bolting cloth installed according to directions given on p 234 Bolting cloth may be of whatever

grade and size of mesh the operator desires However, for most plankton purposes involving both qualitative and quantitative work, *No 25 standard* is the grade usually used From each of the figure-eight connecting loops on the upper ring there extends a piece of strong, nonelastic cord to a corresponding loop on the *headpiece* at the lower end of the silk sleeve. The length of these three cords is adjusted to carry all of the weight of the headpiece and the attached plankton bucket Consequently, the silk sleeve always shows a certain amount of slack. The brass headpiece, constructed from telescope tubing, is 3.5 cm long and has an outside diameter of 5 2 cm. A small peg on the outside surface serves as a part of the safety lock when the plankton bucket is attached Two similar pegs, near the upper rim and 180° apart, fit into holes in the clamp and hold it in position

Details of construction of the plankton bucket are presented in Fig. 66. The body of the bucket is of brass telescope tubing. It has a length of 9 cm. and an inside diameter of about 5.2 cm The upper portion, about 2 8 cm long, serves as a sleeve which fits over the headpiece attached to the bolting cloth. From the upper edge of this sleeve there extends downward an L-shaped cut so constructed that when the plankton bucket is fitted over the lower part of the headpiece the peg on the latter fits snugly into the cut forming a safety lock, sometimes referred to as the bayonet clutch Two such locks oppositely placed are sometimes provided Most of the lower part of the bucket is occupied by four windows each about 3 cm wide and 5 cm long The windows are separated from each other by a narrow band about 1.1 cm. wide, on the inside of which is soldered in a vertical position a semicylindrical piece of brass having a diameter of about 6 mm. These semicylindrical pieces strengthen the strips of tubing. The bottom of the bucket is a conical piece of cast bronze soldered into the end of the tube flush with the lower edges of the windows. This bottom slopes toward the middle, ending in a tapering outlet tube about 2 3 cm long. This outlet tube has a diameter at the upper end of about 2 3 cm., at the lower end, about 1 cm Its walls are about 1 mm thick A tapering removable plug, exactly fitting the outlet tube, has a handle which extends slightly above the upper rim of the bucket and bears on its free end a milled head.

The *large net* has the same shape and general construction as the *small net* Its upper ring has a diameter of 25 cm., the lower ring, 30 cm The canvas sleeve and the bolting-cloth sleeve have lengths of 33 cm and 70 cm , respectively

For most purposes the *small net* is preferable to the *large net.*

The loops, eyes, and connecting wires of the upper section allow it to collapse when not in use This is convenient in packing and transportation However, if a collapsible upper section is not needed, it may, with advantage for some purposes, be made of sheet copper or brass

COMBINATION SAMPLER AND COLLECTION DEVICES

Various types of equipment in which the two operations of sampling and separation of plankton from the water are simultaneous have been devised The three described here are probably the most useful for ordinary purposes Only net plankton is secured by these instruments.

Juday Plankton Trap

The general construction of the Juday plankton trap is indicated in Fig. 67. Form and size may differ depending upon the desires of the operator, but a good, general utility type is described below All parts are made of brass or other nonrust metal.

The trap consists primarily of (a) a frame, 46 × 22.5 × 25.5 cm, supported at the four corners by pieces of cylindrical brass tubing, (b) a box made of thin sheet brass, the four vertical sides of which are immovable, the top and bottom are open but may be closed by lids moving horizontally in close fitting grooves, (c) an open part of the frame, 43 × 24 cm. in horizontal dimensions, having a fixed floor of thin sheet brass; (d) a spring mechanism which operates the sliding doors, (e) a device for releasing the doors and allowing them simultaneously to close the brass box when tripped by a messenger; (f) a short-form plankton net with straining sleeve of No. 25 silk bolting cloth and a detachable bucket of the usual construction, attached to the lower door and opening into the interior of the box through a large circular hole, (g) four supporting chains radiating from a central attachment disk to the tops of the four corner posts and forming suspension for the entire trap, and (h) accessory items as follows an opening with short piece of brass tubing on the upper surface of the lower fixed floor, covered by a small, fine-mesh cloth bag, permits air to escape from the plankton net when the trap is lowered into the water, a similar hole and tube in the middle of the top door, covered by same kind of cloth bag, permits air to enter the closed box when it is lifted out of the water after a catch; a small rectangular window in the upper part of the side toward the open section of the frame closed by very fine brass gauze also serves a function similar to that of the opening in the upper lid.

Operation of Plankton Trap

1. Provide suitable hoist with which to operate trap Ordinarily it is not practicable to use trap by hand. Hoist should be provided with graduated rope or wire cable. A hoist with swinging arm (Fig 51) which makes it possible to deliver trap and enclosed catch onto deck of boat is preferable Graduation of rope or cable may be eliminated if hoist is equipped with rope meter.

2 Thread free end of hoisting line through mid-channel in brass messenger Be sure that messenger slides down line with minimum friction. A split messenger, if available, can be put on line at any time or place

3 Pass free end of hoisting line through hole in upper stirrup of trip mechanism and on through hole in middle plate of suspension chains below, knot or otherwise fasten securely

4 Adjust hoist and hoist arm so that when in operation the trap will

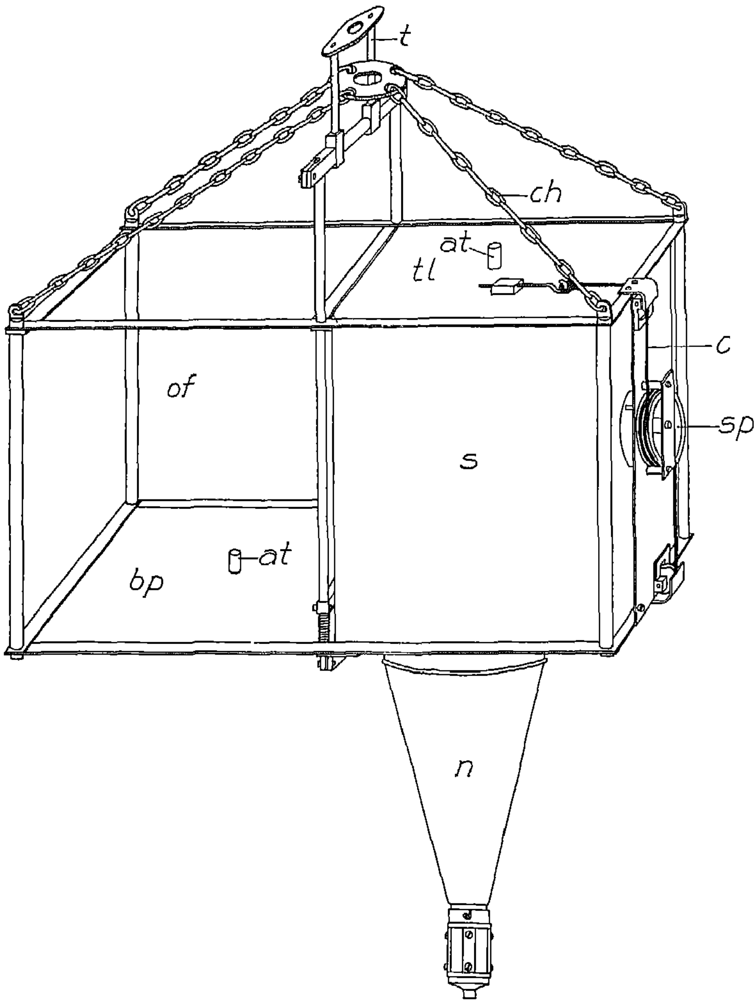


FIG. 67 Side view of Juday plankton trap, shown in closed position (*at*) Air tube (*bp*) Bottom plate (*c*) Operating cord (*ch*) One of four supporting chains (*n*) Plankton net. (*of*) Open frame. (*s*) Side plate. (*sp*) Operating spring. (*t*) Top part of tripping device. (*tl*) Top lid

be lifted out of the water to proper height and will make no contacts with hull of boat

5 With trap suspended in air, pull upper and lower lids over open part of frame until trip mechanism engages and holds them in new position Inspect all parts of apparatus to insure good working condition, for trial purposes, trip instrument to see if lids close freely, quickly and completely.

6 With trap set in open position, lower slowly and carefully to desired depth, release messenger, bring trap slowly to surface, lifting it entirely out of water and allowing trapped sample to drain out through plankton net until desired concentration is effected in plankton bucket, transfer catch to proper containers for further use

7. If succeeding sample is to be from a new depth, wash interior of collection chamber, plankton net and plankton bucket with tap water

Advantages

The plankton trap has the following advantages

a Collection of sample and removal of net plankton are accomplished simultaneously in the field

b The sample is taken from the desired depth position, with negligible mixing of water from other levels

c Loss of plankters due to reactions to water current is avoided

d Uniform quantities of water are taken in each sample

e Plankton sampling is accomplished with considerable speed

Limitations

a. The plankton trap is bulky, a little awkward to handle, and heavy when partly or wholly filled with water Some kind of hoist is usually a necessity.

b Only net plankton samples are taken, and it is not practicable to attempt to recover quantitatively the filtered water.

c. The plankton trap can be used only in relatively calm water

d. The plankton trap can be used only in situations free from water plants and other objects which would interfere with the operation of the instrument

e Use of this instrument in very shallow water is likely to result in damage to the suspended plankton net

General Considerations

a The plankton net must receive the same care as that described for other nets on p 253 In preparation for long-distance transportation, the net should be removed from the bottom lid and packed separately In transportation to and from the field it should be carefully turned partly inside

out through the large opening in the bottom lid into the collection chamber and all metal parts wrapped in soft packing to prevent injury to the bolting cloth

b A specially designed carrying case or kit is a necessity

c The grooves in which the lids operate must be kept free from grease or gummy substances. They should be cleaned carefully from time to time

d Operation of the plankton trap depends upon the proper alignment of lids and their grooves, proper tension of the operating spring, proper functioning of the tripping device, and good condition of the plankton net

e It has been claimed (Ricker, 1938, and others) that certain plankters, notably *Daphnia*, are able to "see" a plankton trap during day sampling in the uppermost waters and avoid it, thus leading to the loss of a certain fraction of the reacting plankters To what extent this is an error of consequence remains to be determined.

f Clarke (1942) has modified the plankton trap as originally described by Juday by (a) having the sliding doors, in open position, on opposite

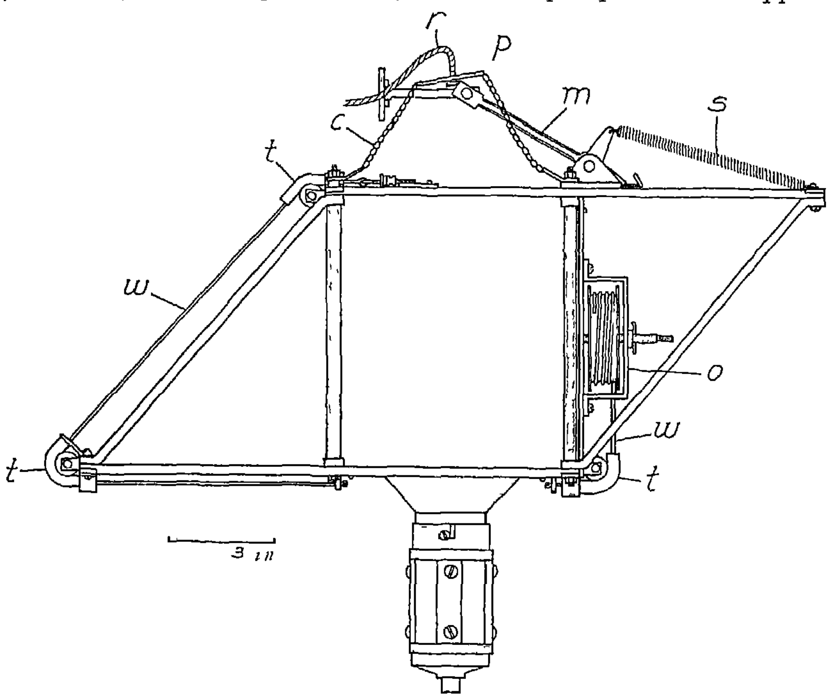


FIG 68 Side view of Clarke's modification of Juday plankton trap, shown with doors in closed position (*c*) Supporting chain (*m*) Trip mechanism (*o*) Operating spring (*p*) Metal plate to which supporting chains are attached. (*r*) Draw rope (*s*) Coiled spring. (*t*) Metal tube to keep wire on pulleys (*w*) Wire for operating doors of trap (From Clarke, 1942.)

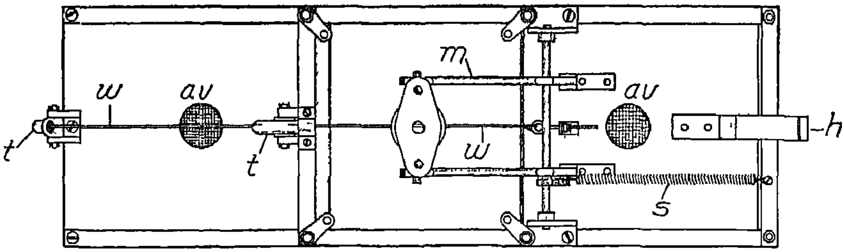


FIG 69. Top view of Clarke's plankton trap with doors in open position (*av*) Air vent covered with fine wire screen (*h*) Handle. (*m*) Trip mechanism (*t*) Metal tube to keep wire on pulleys. (*w*) Wire for operating doors of trap (From Clarke, 1942.)

sides thus providing an even distribution of weight and a better balance, (b) reducing the capacity to 5 l., (c) providing a different mechanism for controlling the action of the sliding doors, making their performance more certain, (d) omitting the plankton net (sleeve) and straining all of the trapped water through the plankton bucket, and (e) passing the operating wire through sections of metal tube so located and constructed that the wire cannot leave the pulley. Figs. 68 and 69 indicate the essential features of the revised sampler.

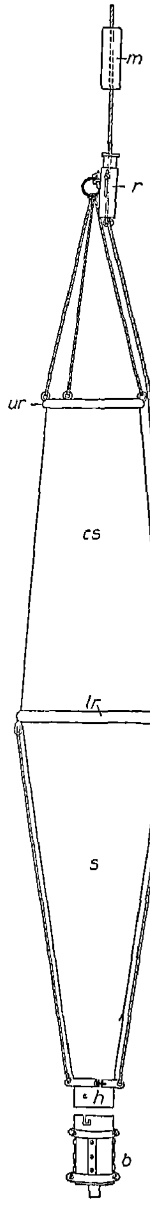
Closing Nets

A closing net is so constructed that it can be lowered into the water to a selected position, made to function from that point by drawing it through the water, then closed at the conclusion of the haul, and the catch brought to the surface without further additions to the sample. A closing net now in common use consists essentially of a long truncated cone composed of light canvas or heavy muslin, a long straining sleeve of silk bolting cloth or other material also in the form of a truncated cone, a removable plankton bucket of the form described on p 241, and a mechanical release operated by a messenger. Fig 70 indicates the principal features of construction. At the upper end of the canvas sleeve a brass ring, 12 cm in diameter, is sewed firmly into place From this ring radiate three supporting cords, equidistantly placed, which converge to attachment to a small brass ring. At the lower end of the canvas sleeve, another brass ring, 17 cm. in diameter, is also sewed firmly into place slightly above the edge of the sleeve so that a margin of the latter, about 2 cm wide, extends below the ring. The canvas sleeve is 40 cm long.

The straining sleeve is about 47 cm. long, is sewed to the projecting margin of the canvas sleeve below the larger supporting ring, and is attached at the lower end to the brass headpiece which receives the plankton bucket Three cords, equidistantly placed and extending from the ring at the top of the straining sleeve to the headpiece, are so adjusted in length

that they carry all of the weight of the headpiece and bucket thus allowing the straining sleeve to hang loosely

The main draw line is attached to the brass ring at the bottom of the canvas sleeve At a point on this draw line equal in distance to the combined length of the canvas sleeve and the three supporting cords and their ring, a knot is tied, determining the lowermost position of the tripping mechanism. The trip is threaded onto the main draw line and rests upon this knot. The construction of a suitable trip *r* is indicated in Fig 70; when a messenger of suitable shape and weight is sent down the draw line it strikes the top of the trip, opening the release mechanism.



Operation of Closing Net

1. Attach plankton bucket securely on headpiece at lower end of straining sleeve Hold main draw line high enough in air so that net is suspended vertically. Lift canvas sleeve into vertical position, push down plunger of trip and hook ring at upper end of suspension cords over upturned hook of trip between two guard wires, release pressure on plunger and allow ring to be locked into place The whole net is now suspended in a vertical position.

2. By means of graduated main draw line, or by use of recording meter and line, lower net promptly until top of canvas sleeve is at lowermost depth level of horizontal stratum through which sample is to be taken, then draw net slowly but steadily upward (rate about 0.5 m per sec) until top of stratum is reached Send down messenger which, on striking plunger of trip, releases suspension ring in top of net, allowing entire canvas sleeve to fall over and assume a reverse position, transferring weight of whole net to lowermost end of main draw line, and causing supporting ring at top of straining sleeve to take an edgewise position. Thus the net is effectually closed.

FIG 70 Side view of closing net of usual type (*b*) Detachable bucket, shown detached from headpiece (*cs*) Canvas sleeve (*h*) Headpiece (*lr*) Lower ring (*m*) Messenger (*r*) Release (*s*) Sleeve of silk bolting cloth, or other suitable material (*ur*) Upper ring Third supporting cord, extending from lower ring to headpiece, not shown in figure

3 Bring net to surface by steady lifting motion and secure plankton catch by procedures described on p 276, also see same page for directions for washing net and bucket with tap water

Limitations

1 The closing net takes a sample only when drawn through a stratum of water having considerable thickness It is not suitable for securing samples from one restricted region

2 It is not suitable for work in very shallow water

3 It must be used in calm weather since rough water may cause contamination of the sample

4 Theoretically, and under ideal conditions of operation, a closing net strains a column of water with a diameter of that of the upper ring of the canvas sleeve and a length equal to the distance through which the net was pulled prior to closing Actually, this result is seldom completely attained Much depends upon the speed of pull Excessive speed results in overspill at the receiving end of the net, undue slowness also gives uncertain results An approach to the optimum speed depends upon a combination of good judgment by the operator and some test trials made before the work is begun Suitable speed of pull also depends much upon the size of the mesh in the straining sleeve, also upon abundance of plankton and the rate at which the meshes of the net become more and more clogged. It is likely that under most circumstances the operator should not expect an efficiency of more than about 80 per cent, often less, in quantitative work

5 When plankton is scanty, and the thickness of the selected water stratum is small, workable concentrates can be secured only by repeated draws through the same stratum However, in several hauls in succession the efficiency of the net diminishes due to clogging

6 Closing nets of the type described here are designed primarily for vertical hauls With special technic and accessory equipment, oblique and horizontal hauls may be made but ordinarily must be regarded as impracticable

7 When used in daytime it is claimed (Ricker, 1938, and others) that an error arises because certain plankters, notably *Daphnia*, are thought to be able to see the plankton net in the upper waters during the day and avoid it, thus leading to a certain loss Whether such a loss occurs generally, and to what extent, remains to be determined

Advantages

1 Collection of sample and plankton in the field is simultaneous

2 Loss of plankters because of negative reaction to current is minimal

3 A transverse section of the plankton of a body of water or any stratum of such water is secured

4 Collections may be made easily and rapidly by one person.

5 For qualitative work of a reconnaissance type, the closing net is rapid and effective.

General Considerations

a If properly done, the necessary lowering of the net *open* involves no entry of plankters from strata other than the selected one

b. The straining sleeve may be made of any grade or mesh of silk bolting cloth, grit cloth, or other appropriate fabric, depending upon the needs of the work in progress

c. Because of its large size and its general delicacy, a closing net should always be transported to and from the field in a specially designed case

d. On return from the field, closing nets should be suspended full length in the air, in subdued light, and allowed to dry at once.

e. When wet, the canvas sleeve becomes watertight and allows no net plankters to enter through its sides

Clarke's Plankton Sampler

Recently a sampler (Figs 71 and 72) has been devised by Clarke and Bumpus (1940) which overcomes some of the more serious limitations of the ordinary closing net This is the most satisfactory closing-net type of quantitative plankton sampler that has been produced. The principal features are (a) a brass tube about 6 in long and 5 in in diameter, (b) a straining sleeve of bolting cloth of some desired grade attached to the rear of the brass tube by means of a ring with a bayonet lock, (c) a brass frame which carries the brass tube on pivots and which provides attachment to the draw cable, (d) two vanes, one on each side of the brass tube, so set that they assist in holding the tube in a horizontal position, (e) a disk-shaped controlled shutter, mounted on vertical pivots, in the front end of the tube, (f) a large propeller mounted within rear half of tube and geared to a counter which registers the number of revolutions and consequently the volume of water which passes through the tube and the net, (g) messengers, triggers, lugs, draw-line weights, and other accessories necessary to the functioning of the apparatus The draw cable is attached by a device which allows the supporting frame to swivel freely about the cable, thus insuring that the open end of the tube is always forward when the net is being towed

Calibration Before this instrument can be used for quantitative work, the propeller-counter mechanism must be calibrated in terms of liters of water filtered per revolution of the propeller Such calibration must be done in some properly equipped laboratory by passing known volumes of water through the tube at various speeds It is said that, in instruments made according to the specifications of the inventors, the rating would be

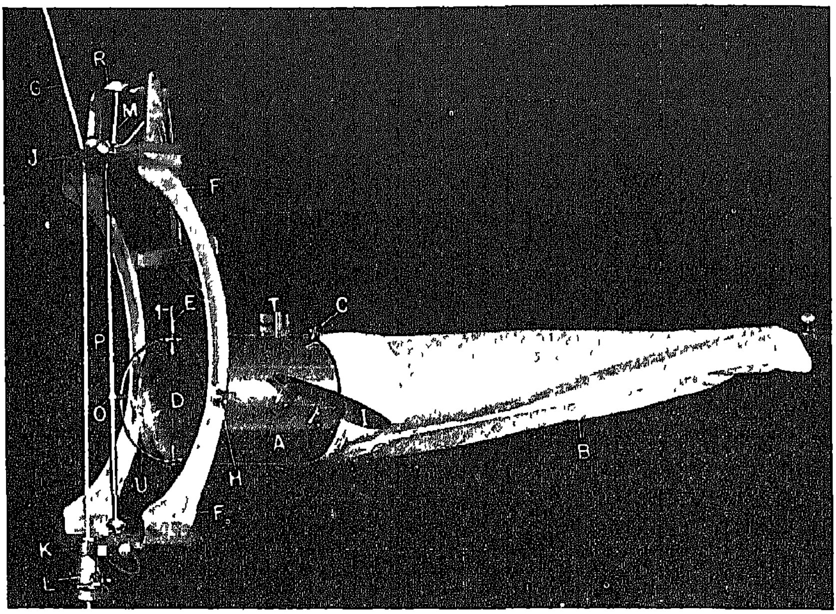


FIG 71 Side view of Clarke and Bumpus plankton sampler attached to supporting cable and with shutter in initial closed position. The receptacle at the free end of the net and the drag which holds the net in a straight position are not shown in this figure (*A*) Tube. (*B*) Net (*C*) Bayonet lock (*D*) Shutter (*E*) Pivot for shutter (*F*) Frame (*G*) Cable (*H*) Pivot for tube. (*I*) Plane (*J*) Spring pin. (*K*) Gate lock (*L*) Supporting clamp. (*M*) Rod fixed to trigger. (*O*) Long finger lug (*P*) Rod. (*R*) Trigger (*T*) Counter (*U*) Semicircular bar (*1*) Spring (From Clarke and Bumpus, 1940)

found to vary less than 5 per cent when operated under boat speeds of about one-half to 4 nautical m. p h Such a constancy makes it unnecessary to know precisely the boat speed as long as it is within these limits

Operation of Net

1 Before instrument is attached to cable, set shutter in tube as follows Turn shutter to final closed position with semicircular bar inside tube; rotate shutter 90° counterclockwise against spring, at same time rotate lug rod clockwise against its spring until edge of shutter engages longer lug, make necessary adjustments of trigger mechanism, continue rotation of shutter counterclockwise for another 90° and rotate lug rod clockwise until semicircular bar of shutter engages shorter lug and trigger rod engages proper horizontal arm Make certain that proper spring tension is present in this position to insure prompt return of shutter to former positions when released, if not, remove stops and give shafts additional turns

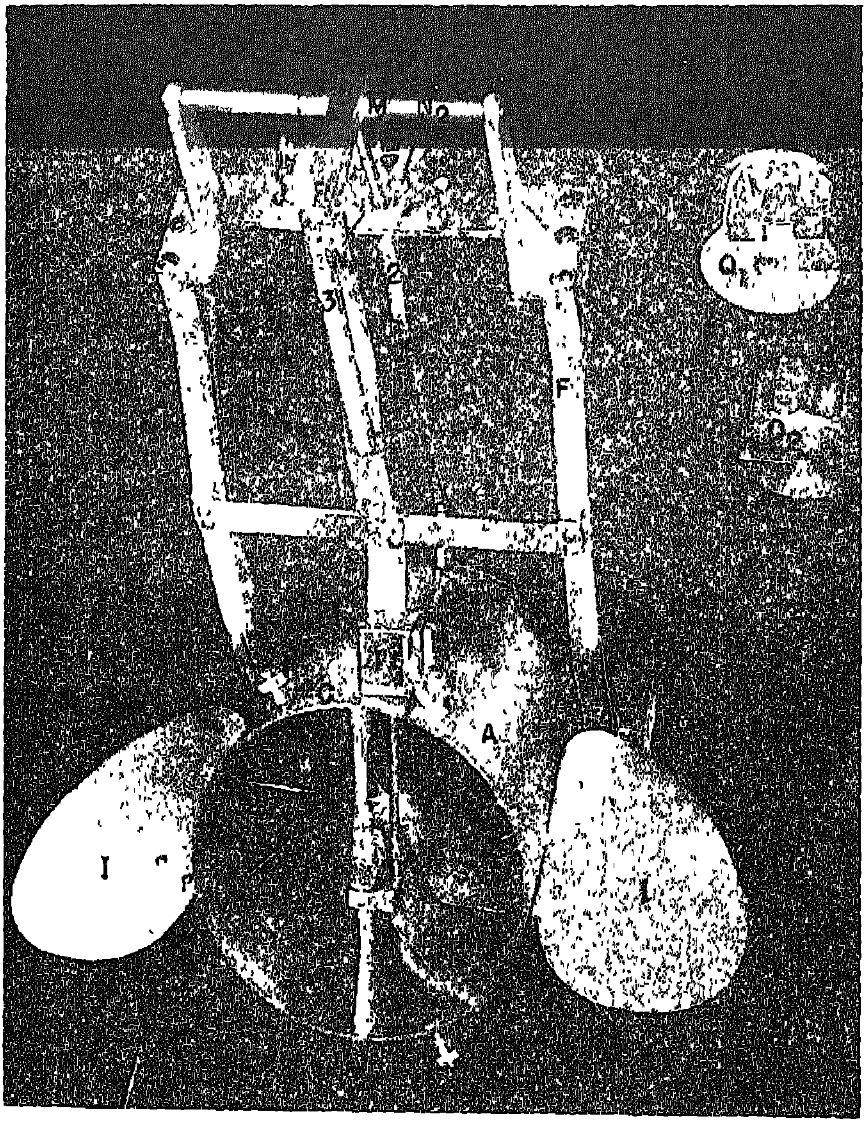


FIG 72 Rear view of Clarke and Bumpus plankton sampler; net has been removed. (*A*) Tube (*C*) Bayonet lock (*F*) Frame. (*I*) Planes (*J*) Spring pin (*M*) Rod fixed to trigger. (N_1, N_2) Arms in cap (*P*) Rod (Q_1, Q_2) Messengers. (*R*) Trigger (*S*) Propeller (*T*) Counter (*V*) Escapement rod. (2, 3) Springs. (From Clarke and Bumpus, 1940)

in direction opposite their direction of operation, shutter is now in operating position

2 Fasten instrument to cable, carefully following directions supplied by maker

3 Record position of dial on counter

4. Attach weight to lower end of cable.

5 Start boat forward, lower instrument slowly into water, if tail of net shows tendency to whip forward, attach to it a drag (tin funnel drawn mouth forward by three equidistantly spaced converging pull cords, or similar device) to insure that it pulls in proper position

6 When ready to begin making plankton catch, slip messenger onto cable, drop messenger causing shutter to rotate 90° into *open* position; water now entering mouth of tube passes through propeller and is measured quantitatively, then on into net through which it flows, leaving net plankton behind in terminal collecting cup

7 At end of selected towing period, send down second messenger which causes shutter to rotate another 90° and close aperture of tube, thus ending collection.

8 Bring instrument to surface and secure catch in usual way

Advantages

In addition to possessing some of the same advantages presented in the ordinary closing net (p 248), this instrument has the further ones listed below

a The meter records exactly the amount of water which passed into the net

b Any clogging of the net as the tow proceeds is no source of error

c The instrument is particularly suited to horizontal tows. In addition, with proper arrangements, it can be used for vertical and diagonal hauls.

d Overspill of water at the mouth of the net due to excess speed of towing is of no consequence

e Calm water is not necessarily required

f In waters of large size and depths, two or more of these samplers may be operated simultaneously on the same cable, each at a depth different from that of the others

g It is usable from boats of any ordinary size, even rowboats operated by oars

h The plankton may be caught over a considerable distance, making the catch more representative because of irregularities in horizontal distribution

Limitations

1 Clarke's sampler is not suitable for very small or very shallow waters

2 It does not give a sample from one very restricted position

3 It gives no measure of nannoplankton, nor does it make possible the securing by some other method of the nannoplankton from the column of water strained

General Considerations

a If the closing shutter is not required, a greatly simplified and less expensive form of the instrument may be provided in which the tube, meter, and net are combined in the same way but mounted on a simple, light, rectangular frame.

b All working parts should be kept well lubricated If long intervals are to exist between times of use, the meter should either be taken apart and dried, or it should be flushed with kerosene and filled with motor oil

c If sampler is to be used in sea water or in inland saline waters, it is recommended that all parts of the instrument be nickel plated in order to avoid corrosion Skunk oil is recommended as the lubricant in salt water After each use the salty water must be washed from all parts of the instrument and in particular the meter The meter may be kept full of some heavy grade of motor oil.

d Special attention must be given to the strength of the cable and its attachment to insure against loss of the instrument

e This instrument must not be operated through beds of aquatic vegetation, in waters containing submerged objects, or close to the bottom

f A modified form of oblique haul may be made by starting the haul at the deepest selected depth and towing the instrument horizontally, but periodically shortening the cable until all selected levels have been sampled

CARE AND REPAIR OF PLANKTON NETS

a In storage, plankton nets should be hung from hooks, in normal position, away from contacts with other objects, and in subdued light Silk deteriorates rapidly when exposed to direct sunlight

b After a net has been used in water, it should be dried promptly by hanging it in open air away from direct sunlight

c A plankton net is very delicate and must at all times be carefully protected During transportation to and from the field, it should be stored, preferably hung, in some suitable container. The small Wisconsin net may be easily suspended within the neck of a large milk can

d. Holes and slits, due to age, wear, or accidents, may be repaired temporarily by the use of soft paraffin, beeswax, rubber cement, or some similar waterproof material.

Settling Method

The settling method has a limited but sometimes important use. It is based upon gravity settling of plankters in plankton-bearing water after the addition of a killing and preserving agent. It may be operated as follows

1. Provide several duplicate glass tubes having diameter of any convenient size (not less than 1 5 cm., preferably larger) and length of not less than 80 cm., also provide suitable rack for storage of such tubes in vertical position Clean tubes thoroughly. Attach to each tube a permanent serial identification number.

2. Ascertain capacity of each tube up to graduation mark located near top of tube, record this value in some permanent form on outer surface of tube.

3 Install tubes, and supporting rack in small darkened room which can be locked to insure against disturbance.

4 Secure desired samples of plankton-bearing water by means of sampler and deliver into sample bottles, bring to laboratory immediately Invert sample bottles several times to offset possible settling effects during transportation, then pour samples into tubes mentioned above, filling them to graduation mark. Divide one sample among several tubes, or use only one tube per sample if capacity is adequate

5 To each tube add sufficient 10 to 15 per cent formalin (or other suitable killing and preserving fluid) to produce quick killing and preservation of all plankters.

6. Close tops of tubes to prevent evaporation and entry of dust. Allow to stand in closed, darkened room for about two weeks. At end of that period most of total plankton will have settled to bottom of tubes. Draw off very carefully, by siphon or pipet, all of upper five-sixths or more of water column, avoiding removal of settled material.

7 Stir remaining portion of water column, preferably by gentle swirling, until all settled materials are again in suspension, then transfer to another long tube, but much smaller in diameter, which will hold residual portion from first settling. Again place in isolation room and allow to settle for another period of about two weeks. Then draw off uppermost part of water column For some purposes, sufficient settling and concentration may have been accomplished at this stage, if not, the processes of settling and transferring should continue until it reaches satisfactory degree Usually three to four such settlings and transfers will be adequate for many purposes

GENERAL CONSIDERATIONS

a The operator must use his judgment as to how much of the settled water column can be siphoned off without significant loss of plankters In quantitative work, a certain margin of safety must be allowed since some settled or almost settled materials may not be easily visible.

b In the instance of division of an original water sample among several duplicate tubes, results of the first settling may be combined into one tube of the original lot for the second settling period. However, final steps must usually be accomplished in smaller tubes

c The number of settling periods and the allowable dilution of the final plankton concentrate must be determined by the operator on the bases of practicability and the use to which the concentrate is to be put

d No fixed rule can be stated concerning the length of settling periods For qualitative work, the periods may be much reduced without serious disadvantage, for quantitative work, preliminary tests on the plankton of the selected waters may be of service in arriving at a dependable settling period

ADVANTAGES

a This method involves a minimum of equipment and can probably be operated with materials regularly found in any laboratory.

b For qualitative work, this method has the virtue of providing plankters which are free from breakage, crushing, or other forms of general damage inherent in net or centrifuge treatment.

DISADVANTAGES

a The long periods of time necessary for settling are sometimes a serious disadvantage.

b In plankton-poor water, the required large size of the sample demands the use of many duplicate tubes if an adequate amount of concentrate is to be secured.

c. Determination of the required settling period for different waters may require preliminary tests

d. A measure of the possible loss of plankton in the removal of overlying water is almost impossible to determine in any precise way.

e. Living plankton concentrates cannot be secured by this method.

Plankton Centrifuges

Of recent years centrifuge methods have become firmly established in plankton work, particularly when the nannoplankton is of major interest, or when total plankton is to be measured volumetrically or gravimetrically

Various types of centrifuge are in use but the one described below comes more nearly qualifying as a standard instrument

FOERST ELECTRIC CENTRIFUGE

The principal features of the Foerst centrifuge appear in Fig 73. The form commonly used has a maximum speed of 20,000 r p m It is of the revolving-bowl type in which the organisms are deposited in the angle formed by the junction of the side wall of the bowl with the bottom The plankton-bearing water enters at the top and the centrifuged water is thrown over the rim of the bowl A rheostat control permits adjustment of speeds within the ranges inherent in the instrument

Operation of Foerst Centrifuge

1. Oil principal shaft bearings before starting run As commonly made, centrifuge has three places for oil, two on upper section of main shaft, and one at lowermost end of shaft below motor, all closed by screws with "oil" stamped on head. Remove "oil" screws and put into each hole about 3–4 drops of some good grade light oil, such as sewing-machine oil, then replace screws This quantity of oil will usually serve for at least 1–2 hrs of steady running Carefully avoid adding more oil than necessary.

2 Set up centrifuge as indicated in Fig 73 Use some type of support or frame for firm installation of all items of equipment. The support indicated in Fig 73, designed by the writer, has been very satisfactory Put base of centrifuge on a rubber mat or thick felt pad to reduce noise and vibration In this figure r^1 and r^3 are iron rings of the ordinary ring-stand variety, diameters of which are suitable for the selected funnel and sample bottle, r^2 is a similar ring, of smaller diameter and with a section removed to facilitate introduction of neck of sample bottle

3. Adjust glass funnel with its terminal rubber tubing and pinch cock so that water is delivered into centrifuge without danger of loss Start centrifuge, building up speed to operating level, and pour tap water into funnel, control delivery of water into centrifuge by pinch cock, use this step as trial to test complete working order of apparatus.

4 Set centrifuge at selected operating speed by means of graduated rheostat knob, or with cap of centrifuge chamber removed, determine speed by applying speed indicator to end of revolving shaft, replacing cap when proper speed is determined

5 With upper ring (r^1) lifted higher than its working position and with the middle ring (r^2) fixed at proper level, remove stopper from sample bottle, and, with a quick motion, invert bottle containing sample into funnel with mouth about halfway into it, slip bottle in place in middle ring and bring upper ring down over bottom of bottle in supporting position Water flowing from sample bottle will rise in funnel to certain level

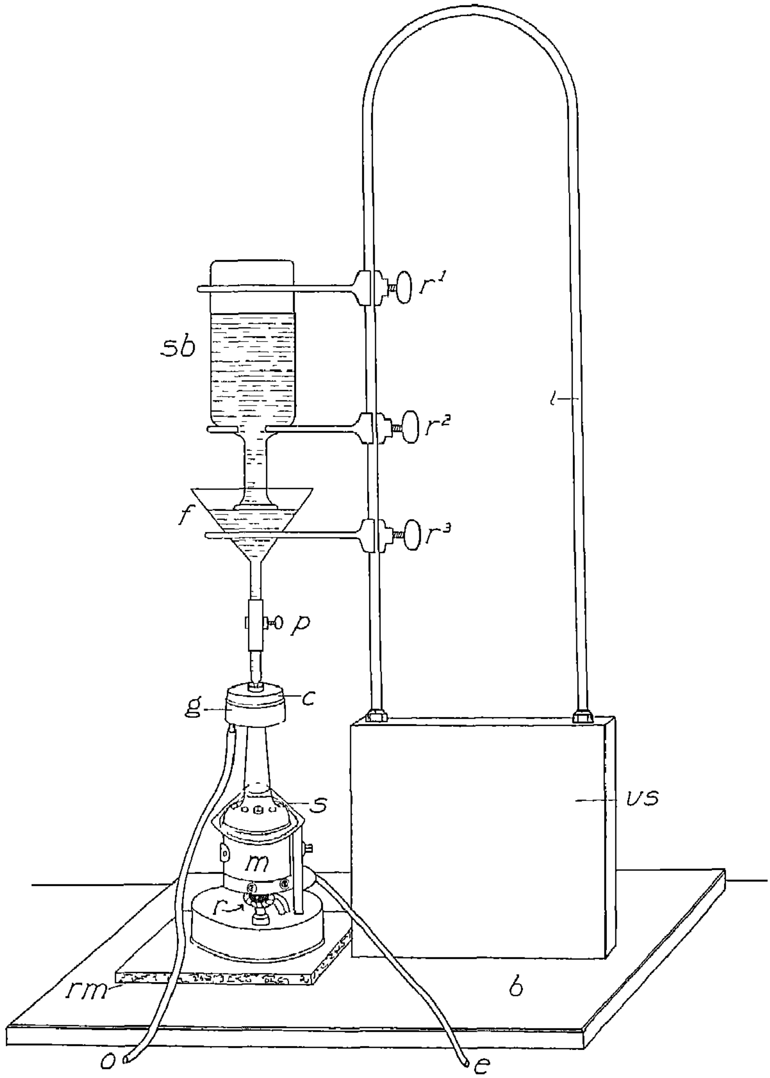


Fig 73 Foerst electric plankton centrifuge set up in operating position (*b*) Base of support (*c*) Cap of centrifuge chamber (*e*) Electrical connection to motor. (*f*) Funnel (*g*) Housing of revolving bowl (*i*) Iron rod support (*m*) Motor (*o*) Outflow tube (*p*) Pinch cock (*r*) Rheostat (r^1, r^2, r^3) Iron rings from ring stand (*rm*) Rubber mat. (*s*) Metal shield (front cut away to show top of motor beneath) to protect motor from water dripping from bowl (*sb*) Sample bottle (*vs*) Vertical wooden support for iron rod

but will not overflow, further inflowage of the sample into funnel will depend upon outflow past pinch cock into centrifuge When proper adjustment of outflow is made by pinch cock, delivery to centrifuge becomes automatic and should continue until sample bottle is emptied

6 Adjust screw pinch cock so that proper rate of flow into centrifuge is provided If centrifuge tends to slow down in speed, shows signs of laboring, or shows a tendency for water to be forced to outside at edge of cup, delivery of sample water is too rapid Crowding of centrifuge leads to imperfect results, too slow delivery of sample water does no harm but unduly prolongs time of running sample Operator will soon learn to detect correct adjustment The small Foerst centrifuge will usually require about 7–10 min. per l. of sample

7. Maintain centrifuging speed for short time after water disappears from stem of funnel to insure that all of sample has passed through instrument and only a small quantity of water remains in bowl Turn off current and stop centrifuge Remove tip of funnel delivery tube from centrifuge and with back-and-forth rotary motion remove cap from top of centrifuge, exposing interior of bowl

8 Slip specially made wrench into narrow space between lower end of motor and upper surface of centrifuge base and engage the lower projecting end of main shaft, thus immobilizing it. Grasp upper rim of rotating cup in bowl and turn *clockwise*, unscrewing cup and removing it from machine. Cup will contain small amount of water Plankton accumulation tends to be compacted into angle between floor and sides of cup. By means of piece of soft rubber tubing, cut diagonally at one end to form elongated tip, and other end slipped on a glass rod for support, very gently brush loose compacted plankton from bowl Pour plankton concentrate into selected receptacle; add small amount of distilled water (about 1 cc) to bowl and wash carefully to secure plankters possibly still remaining, add residue so collected to concentrate in receptable, repeat washing at least once

9. Wash bowl and inside of removable cup with distilled water, dry with suitable absorbent cloth or sponge, hold main shaft by means of wrench at lower end below motor and replace bowl by screwing it counterclockwise onto shaft, replace top of cup Centrifuge is now ready for another run or for storage

10. On completion of use, store centrifuge by laying it on its side, thus safeguarding against possibility of oil running down into motor from upper bearing

General Considerations

a Size of sample centrifuged will depend upon the wishes of the operator and upon the richness or paucity of the plankton For ordinary

purposes, one liter is sufficient when plankton is at least moderately abundant, for plankton-poor waters, two or more liters may be required

b For removal of all kinds of plankton, the centrifuge should be operated at about the maximum speed (20,000 r. p m). For separation of certain groups of plankters, the centrifuge may be made to exercise a limited differential sorting effect by the use of lower speeds Differential effects of different reduced speeds must be determined by preliminary experimental tests

c Protective shield (Fig 73, *s*) installed just above the motor will protect against water from the bowl finding its way into the motor

d When operated at about 20,000 r. p m , the Foerst centrifuge, in the first run, will remove about 98 per cent of the plankton, exclusive of bacteria. Some bacteria, perhaps 25 to 50 per cent, are also included A second run of the water from the first run will remove most of the remaining 2 per cent. Certain Algae are particularly resistant to centrifuging, as for example, *Aphanizomenon*, of which only about 50 per cent may be secured in the first run In ordinary kinds of plankton work the first run will often suffice, the remaining error falling within the general error of other operations involved.

e Disposal and use of material secured with the centrifuge depends upon the aim of the work. If it is not to be worked immediately, preservative should be added as soon as material is collected

f On all occasions when the bowl is replaced in the instrument, it should be screwed snugly into place, otherwise it may become loose during a run and wobble. A loose bowl may be detected during a run by the changing sound of the machine.

g. If for any reason, the form of set-up indicated in Fig. 73 is not convenient or desirable, a large aspirator bottle can be used for a feed bottle and if it is fitted with a rubber stopper, a very satisfactory control of rate of flow into the centrifuge can be provided by the use of a glass stopcock

Advantages

a. This instrument combines the advantages of portability, compactness, small weight, ease of use, efficiency and minimal accessory equipment for operation.

b All organisms commonly included in plankton work are removed, only some residual bacteria will usually remain behind.

c Secures material suitable for numerical, gravimetric, volumetric, and microchemical studies

Disadvantages

a Includes all detritus as well as plankton.

b. Requires electric current for operation

c Produces some crushing effect on plankton catch when operated at higher speeds

d Limited capacity results in a certain slowness in handling samples.

e Rather high initial cost.

OTHER CENTRIFUGES

Various centrifuges, with speeds which develop about 50,000 r p. m. have been tried in plankton work It appears that for many kinds of plankton work the added cost and other disadvantages are not justified Larger centrifuges with greater capacity are useful in shortening the time of running a sample, and higher speeds may effect a more complete removal of the plankton during the first run Large, high-speed centrifuges usually require a permanent installation, thus losing the advantage of portability. Initial costs are also much greater Power centrifuges designed for other purposes may be adapted for plankton removal but are likely to be inconvenient and relatively inefficient

The common hand centrifuge is convenient for some of the grosser aspects of plankton collection.

Glass-slide Racks

Glass slides suspended in open water accumulate various microscopic and semimicroscopic organisms common to such situations. For certain kinds of plankton work effective use can be made of this simple technique A convenient form of the method is the suspension from anchored floats

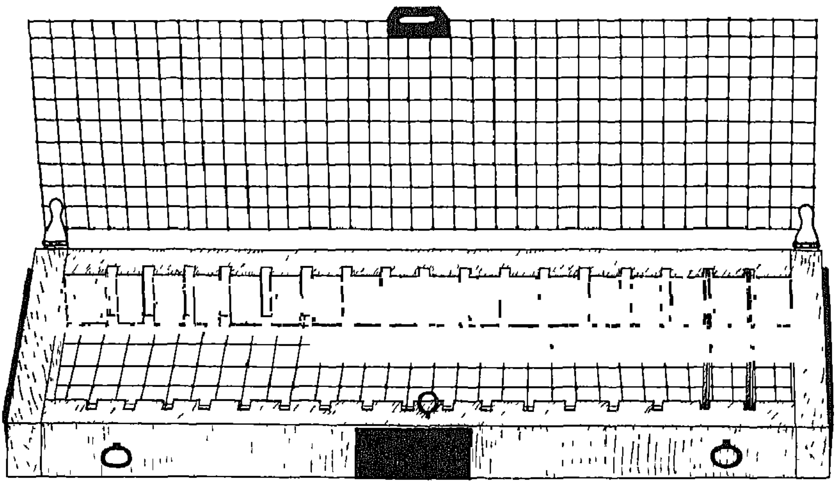


Fig 74 Rack for suspending glass slides in water, shown with lid open and two ordinary 1 × 3-in microscope slides in place in right end. Black areas on each end and on middle of top surface of frame represent pieces of sheet lead which load rack so that it will sink

of clean, ordinary 1 × 3-in. microscope slides in a specially designed rack (Fig. 74) constructed as follows. Fasten two strips of cypress wood, 34.5 × 2.7 × 1.5 cm., and two strips of same material, 7 × 2.7 × 1.5 cm., together to form rectangular frame so that inside transverse dimension will be 7 cm. and longitudinal dimension 31.5 cm. On inner surface of each of longer wooden strips, make 18 saw-cuts so located that those of one side are exactly opposite those on the other, thus forming pairs. Make each saw-cut of such depth that a 1 × 3-in. microscope slide can easily be inserted with extra allowance for swelling of wood and variation in slides. Cover one side of frame with zinc wire screen having mesh of about 0.8 cm. and fasten permanently. To other side of frame, hinge similar piece of zinc screen so that access to interior of cage so formed is provided. On free edge of lid, near middle of its length, solder a piece of sheet brass in which is cut a slender slit so made as to fit over a small brass eye on frame forming a locking device. To outside of wooden frame, attach strips of lead sufficient to insure sinking of rack. Attach one or more brass eyes in outside of frame from which to suspend rack in desired position. All nails, screws, and metal parts other than screen and lead weights should be brass to avoid rusting. Fill rack with clean microscope slides. Number each rack with serial number for individual identification. Such numbering may be done by attaching to frame a brass plate on which number is stamped, or if preferred, number may be stamped plainly on lead plates.

OPERATION OF SLIDE RACKS

1. Fill racks with slides which have been thoroughly cleaned and rinsed.

2. Suspend racks from buoys, piers, or other supports so that they do not make contact with each other or with other objects. Make record of rack numbers, depths, and other pertinent data.

3. Leave racks in suspended position until attachment of organisms occurs. This will require at least several days, in some waters even longer. No fixed directions can be set for period of submergence. In some instances duplicate sets will be advantageous; one set can thus be used as trial set to determine if submergence period has been long enough.

4. At end of submergence period, lift racks slowly, cautiously and only in calm water. Remove from water as follows: (a) if submergence was in the uppermost level of water, completely submerge a large pail in surface water, slip beneath rack when it approaches surface, then lift out so that rack is brought out in pail; (b) if submergence is in a deep stratum in which character of water differs distinctly from surface water, fill pail on deck by securing water from submergence level with a sampler, then bring rack to surface, lift from water very gently and transfer immediately to pail. Transport to laboratory with minimum of agitation.

5 If only a few slides in a rack are to be examined at one time, transfer slides from rack to Petri dishes containing same kind of water from which rack was taken and cover Return rack immediately to original level for continued submergence

LIMITATIONS

a. The slide-rack method is a rough but useful method which merely supplements qualitative work done with more precise methods. In no direct way does it supply any information of a quantitative sort.

b. In plankton studies it is usually most useful for studies made in the uppermost strata When brought from deeper strata there is always the possibility that plankters may be added from the upper water when the rack is pulled through it, although the additions may be few in number.

c. Only those plankters which adhere to objects, or which become associated one way or another with the various other organisms which eventually form a growth on the slide, are collected in this way.

d Slides may collect certain organisms which at no stage could be classified as plankton.

ADVANTAGES

a This method is an excellent means of securing undamaged specimens.

b Plankters on slides are more easily kept alive in the laboratory than in concentrates taken with nets.

c Plankters on slides may be kept alive for some days by storage in refrigerators or ice boxes whose temperatures do not fall to the freezing point

d Information concerning plankters having attached stages may be secured

e. Under some circumstances, this method may aid in the collection of some of the rarer plankters.

f Slide racks may be used to collect plankters in situations in which nets and samplers can be used only with great difficulty.

g Information concerning plankton succession may be secured.

h Plankters may be conveniently killed, fixed and preserved *in situ* on the slide.

Plankton Filters

Plankton filters have been largely superseded by other devices. However, for some purposes they may be convenient and a brief account is presented here For the most part, they are more efficient than silk-bolting-cloth nets in retaining very small plankters. They all have certain disadvantages in common, namely, (a) the filtering process is so slow that it is

difficult to pass through the filter an adequate quantity of the plankton-bearing water, and (b) there is difficulty in separating all of the collected plankton from the filter

FILTER-PAPER METHOD

Samples of water containing plankton may be filtered through hard-surface filter paper fitted in a glass funnel or some other appropriate supporting device after which the collected plankton is washed off the paper into a receptacle Such filtration is very slow unless speeded up somewhat by means of a filter pump Some of the nannoplankters are likely to adhere very closely to the paper and others become caught in its meshes thus making their removal difficult and in some instances almost impossible This method is suitable for qualitative work and with the proper care some kinds of quantitative work are possible, especially if a direct count is made of all of the more numerous plankters For the rarer plankters the method is impracticable since the catch is likely to contain too few of the individuals to make possible a dependable enumeration. Any grade of hard-surface filter paper may be used but it must not be assumed that all such papers give the same results. No. 575 Schleicher and Schull or No 50 Whatman are suitable In records made by the filter-paper method the specifications of the paper used should be recorded in full

SAND-FILTER METHOD

The degree of completeness of plankton removal by sand filters depends upon the condition and quality of the sand used and upon the manner of its use Much detailed information concerning sand filters is available in reference works on sanitary engineering and elsewhere. If ordinary sand is used it must first be thoroughly washed and ignited. However, for most purposes it will be desirable to follow the specification of "Standard Methods for the Examination of Water and Sewage" (9th ed , 1946) which is as follows "White sand is required as a filtering medium This may be Berkshire or Ottawa sand, ground quartz or white beach sand It should be washed and screened, only that portion being used which passes U S Series No 60 screen and is retained on a No 120 screen " Such sand is commonly referred to as *60 to 120 sand* Such sand is satisfactory for ordinary samples However, if it is necessary that very minute organisms be retained, a smaller size of sand grain must be used as for example, 60 to 140 sand In order to function properly, a sand filter must be installed in some specially designed holder

Whipple Sling Filter

The Whipple sling filter (Fig 75) is a simple device convenient for some purposes The cup at the bottom, telescoped onto the funnel and

locked in place by a bayonet clutch, carries a column of sand about 0.5 in deep supported on fine wire gauze The water to be filtered is poured into the funnel, passes through the sand and on out through the open bottom This filtration is speeded up by the centrifugal force produced by whirling the funnel around the handle

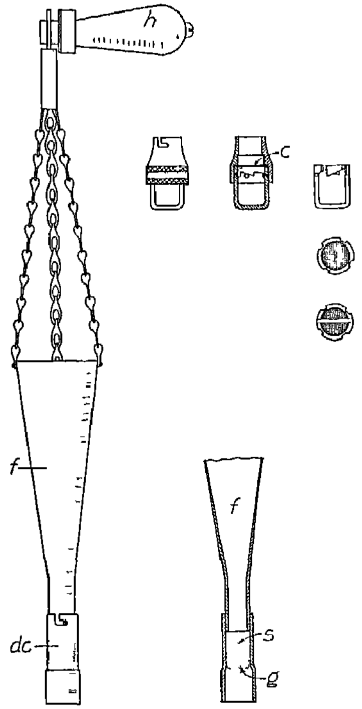


FIG 75 Whipple sling filter and attachments (*Left*) Sling filter assembled and ready for use (*Bottom right*) Sectional view of lower portion of sling with filtering material in place (*Top right*) Attachment for use of cotton disk, in which the cotton rests upon a wire screen and is held in position by a clamp, top and bottom view of supporting screen shown just below figure (*c*) Cotton disk (*dc*) Detachable cup (*f*) Funnel (*g*) Fine wire gauze (*h*) Handle (*s*) Sand (Reprinted by permission from "The Microscopy of Drinking Water," by Whipple, Fair, and Whipple, published by John Wiley and Sons, Inc) (Redrawn)

Cotton-disk Filter

This method consists in passing a sample of water through a thin layer of cotton Whipple devised for this sling filter an attachment (Fig 75, *top right*) whereby such a sheet of cotton can be substituted for the sand layer He also developed the use of cotton-pad collection by the use of a mechanism for filtering a sample of water from one bottle to another (Wizard Sediment Tester) After the filtration is completed the cotton disk is removed, dried, bottom side down, on blotting paper, and the disk mounted on a card and labeled The result of such filtration of a representative sample is the production of a visual, approximate record of the suspended materials in the water produced by discoloration of the disk. This method is not designed to do more than produce such a visual record It is not practicable to try to remove plankton from the disk However, for some purposes this method may be of value in a comparative study in which the mounted stained disks become permanent records Commonly, in making such disk records it will be necessary to ascertain in advance whether the amount of water filtered will produce disks sufficiently colored to make them usable.

Sedgwick-Rafter Method

The time-honored Sedgwick-Rafter method is still the type of sand filter recommended by "Standard Methods for the Examination of Water and Sewage" for sanitary work Equipment for operation of this method consists of the following

1 Funnel Cylindrical glass funnel, upper portion about 23 cm long, diameter 5 cm, and sides parallel, lower portion, diameter diminishing gradually over length of about 7.5 cm until diameter becomes 12 mm, terminal part about 6 5 cm long and 12 mm in diameter Capacity of funnel, 500 cc Funnel sometimes with series of graduation marks

2 Stopper Perforated rubber stopper (Fig. 76) fitted tightly into bottom of funnel, capped on inner end with circular piece of silk bolting cloth having about 200 meshes per inch (linen cloth may be used), cap of silk or linen should be cut with a wad cutter and to a dimension of slightly less than 12-mm diameter, small glass U-tube in stopper, outer end of which extends about 2 5 above inner end of stopper (this device suspends filtration when water in funnel drops to level of its outer end).

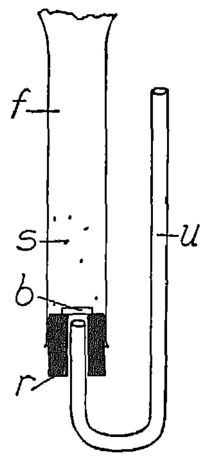


FIG 76 Sectional view of lower end of Sedgwick-Rafter tube with attached U-tube (*b*) Silk bolting cloth (*f*) Lower end of funnel (*r*) Rubber stopper (*s*) Sand. (*u*) U-tube which controls gravity filtration so that water level in funnel cannot drop lower than the outlet level

3 Filter Sand which meets specifications stated on p. 263, must be fine enough to accomplish desired filtration, yet not so fine as to interfere with prompt settling in decantation process, not less than 12 mm deep on top of inner end of rubber stopper, supported by bolting-cloth disk

4. Supports Appropriate supports for funnel, multiple supports in instances of need for several funnels operating simultaneously.

Operation

1 Set up funnel in operating position, pour 5–10 cc distilled water into funnel, then introduce sand to form layer, not less than 12 mm thick, on top of stopper, tilt funnel from side to side to permit escape of air included in sand, flush sides of funnel with stream of distilled water to wash down sand adhering to walls of funnel

2 Fill funnel to top of neck with distilled water and allow drainage

to begin. Mix original sample of plankton-bearing water gently but thoroughly, immediately measure in a graduate that portion of original sample to be filtered (250–1000 cc depending upon abundance of plankters in sample), add measured portion of original sample to funnel, taking every precaution not to disturb sand of filter bed, allow water to filter out, during period of filtration, flush sides of funnel with stream of distilled water from wash bottle to wash down any plankters adhering to sides of glass

3. When water level in funnel reaches level of outlet and of U-tube, carefully remove U-tube and allow all remaining water to drain through filter.

4 Turn funnel into horizontal position and slip small beaker under lower end, with gentle twisting motion, remove stopper slowly, raise funnel to vertical position with lower end inside beaker, allowing sand filter bed to fall out, flush inside walls of funnel with 5–10 cc of distilled water delivered from pipet, collecting water in beaker

5 Mix contents of beaker gently but thoroughly to free plankters from sand and to bring them into suspension, allow sand to settle, then decant immediately into second beaker, add 5 cc distilled water to sand in first beaker, wash and mix thoroughly for second time, and decant again into second beaker Second beaker now contains plankton concentrate ready for analysis With graduate of appropriate precision measure carefully total volume of concentrate so secured

General Considerations

a Gravity filtration commonly requires about 30 min but this time can be much shortened by the use of suction. When suction is employed, it should not be too strong and should be discontinued before water level reaches the constricted portion of the funnel otherwise plankters may be pulled into the sand and damaged Suction is applied directly to the stopper after removal of the U-tube.

b Lodgment of plankters on the glass produces a certain "funnel error." Funnel error may be reduced by the use of (1) cylindrical funnels, (2) suction to speed up filtration, and (3) scrupulously clean funnels

c. The sand error—failure of the sand filter to retain organisms—depends much upon careful choice of size of sand for the filter bed and proper compacting of filter bed prior to the introduction of the sample.

d The original sample should be put through the sand filter as soon as possible after collection in the field to minimize errors of disintegration. In some waters certain plankters may be present which disintegrate quickly after introduction into the storage container Immediate storage in a refrigerator will make it possible to delay filtration for a few hours It is probable that errors of disintegration cannot be avoided entirely but they may be reduced by prompt and careful filtration.

e. In decantation, some plankters are inevitably left behind, also some of the wash water However, with repetition of washing and decantation, together with careful drainage and other safeguards, the decantation error should not exceed 5 per cent (Whipple *et al*, 1927).

f Filtration outfit may be set up using an ordinary glass funnel, about 8 inches in diameter, within which the sand filter bed is supported on a mass of rolled wire gauze or glass wool However, the specially designed cylindrical funnel described above is superior.

Qualitative Plankton Methods

Quantitative plankton methods are often of such a nature that material usable for qualitative work is automatically provided However, it sometimes happens that qualitative plankton studies are in themselves the center of interest, or perhaps a necessary part of some preliminary approach to later quantitative work

COLLECTING METHODS

Any method of collecting plankters for qualitative work may be employed, provided it secures the organisms in good condition and is otherwise suitable Because of the crushing effect of high speed centrifuges, plankton so collected is often in poor condition for identification The pump-and-hose method (p 231) can be used since here its quantitative errors are of no consequence Various kinds of tow nets may be employed, provided their limitations are known Most water samplers are also satisfactory. Slide racks, described on p 260, are sometimes valuable adjuncts to qualitative collection In some waters, the stomach contents of plankton-feeding fishes and of tadpoles yield limited plankton collections of interest. Periphyton surrounding submerged parts of aquatic plants acts as a lodgment place for plankters, also some of the components of periphyton itself comprise certain plankters in their sessile stages

For preliminary purposes, qualitative collections of plankton may be made where and when the operator chooses However, when the goal is an approach to the completeness of a dependable survey, the whole program of sampling and collection must be organized with considerable care, taking into account the fact that waters differ both within themselves and at different times with respect to the kinds of plankters present. Because of the great diversity of waters and the great variety of changes which occur within them, no fixed rules for the organization of a collection program can be laid down The limnologist must either feel his way into an adequate program if no previous data are available, or plan a program with the help of such information as may be available from already existing sources In either instance, proper account must be taken of the following possible differences in the qualitative aspects of plankton populations (a)

in different depths in the same body of water, (b) in different seasons, (c) in day and night, and (d) in different areas of the same body of water, such as the limnetic region, various kinds of littoral regions, especially the exposed littoral, as contrasted with the highly protected littoral, regions, regions of extensive inflow of other waters, regions of plankton drift, and plant beds. Still other conditions may need to be taken into account

IDENTIFICATION OF PLANKTON

Because of the tremendous diversity of organisms composing the plankton of inland waters, the difficulties of identification tax severely the taxonomic skill of even the most experienced worker Ideally, and often practically, it is just as important to the limnologist as to the taxonomist to identify plankters to *species* But with the exception of a certain number of well-marked forms, identification to species must be restricted to those particular groups among the plankters in which the limnologist may have taxonomic command through long experience Beyond this limitation he must count on securing the aid of experts in the other groups involved Commonly, in general plankton work, strict practicality precludes identification of all plankters to species and in many kinds of work no attempt is made to identify beyond *genus* There is reason for believing that, in certain types of plankton work, identification to genus is adequate, however, this point must be settled on the basis of the inherent demands of the work involved In some kinds of plankton work, identifications are made only to family or even order Clearly such gross identification has only limited value By force of necessity, limnologists have been compelled thus far to forego even gross attempts to identify the bacteria and the fungi found in the plankton, depending entirely upon the bacteriologist and mycologist for such aid as can be secured

The beginner cannot be warned too strongly against the risks inherent in plankton identifications Unfortunately there is a deceiving and non-valid simplicity in the taxonomic treatment of plankters in many works dealing with plankton, both in figures and descriptions, which can lead to grave mistakes by the inexperienced It is imperative that one fact be kept in the foreground, namely, that the procedures and problems of making valid taxonomic identifications among plankters are just as crucial and exacting as in other organisms, that only by the same meticulous checking of extended descriptions and other sources of information can dependable identifications be made

CONDITION OF PLANKTON FOR IDENTIFICATION

LIVING MATERIAL Plankton in living form is, in general, vastly superior to any other condition for identification. Unusually active plankters may be slowed down or immobilized by the use of anesthetics or mechanical

means Whenever possible, plankton should be studied immediately after collection Living materials can be kept for some days by storage in an ice box or refrigeration chamber in which the temperature stands at a few degrees above freezing

Preserved Material Unfortunately, plankton collections must, more frequently than not, be preserved for study at some later time No ideal preservative has been found The best of the various preservatives produce effects which may interfere more or less seriously, depending upon the kind of plankter, with identification No preservative has been adopted as a standard by limnologists, although formalin (p 271) has been proposed as such by some workers and it is probably more widely used for general plankton preservation than any other liquid However, some of the shortcomings of formalin have long been known Recently, Lackey (1939) made a critical study of changes in river plankton caused by formalin preservation, listed a considerable number of structural changes produced, and pointed out, among other things, that of 234 species studied, 33 per cent could not be identified to species and many of them not even to genus, while a few were totally destroyed, all of which indicates the great advantage of studying unkilled samples The sudden plunge of a plankton concentrate into killing and preserving fluid often produced severe contraction and distortion of body form of certain rotifers and others, resulting in an object identifiable only, if at all, by the veteran worker Plasmolysis, loss of colors, loss of parts, and other effects may not only lead to puzzling results but may also involve the actual disappearance of some distinguishing characters The worker who is obliged to use preserved samples must be on the alert for misleading effects of the preservative.

Mounting of Material Directions for permanent mounting of plankters do not come within the province of this book The reader is referred to various works on microtechnique for instructions for killing, fixing, staining, and mounting of microscopic and semimicroscopic organisms Temporary water mounts of various living plankters are often usable for several hours Living plankters may be mounted directly in dilute glycerin and so kept in usable form for some time

The worker will be able to devise his own methods for slowing down or immobilizing those plankters which are too active for study. A small crystal of chloretone placed at the edge of the cover glass, chloroform on a bit of cotton attached to the cork in the top of the bottle, 1 per cent cocaine solution added to the water, and other similar treatments will be found helpful

PLANKTON IDENTIFICATION RECORDS

Permanent Mounts Good permanent mounts of plankters, made by the use of carefully selected methods of killing, fixing, mounting, and

completely labeled, have no peer as records of qualitative work Various plankters differ in their microtechnique requirements and the methods are frequently time-consuming, tedious and demanding in experience For details, the reader is referred to standard works on the microtechnique of smaller organisms The inexperienced worker will soon discover the necessity of practice if acceptable mounts are to be secured The proper choice of methods is often critical Careful anesthesia is commonly required in the instance of sensitive, contractile forms. In many kinds of plankton work, time limitations will render permanent mounting impracticable; hence some other form of record will be required.

Drawing and Measurements. For many purposes, rapid but careful drawings accompanied by significant measurements and notes constitute important qualitative records, and often must be used in lieu of permanent mounts. Such drawings should be confined to strictly essential taxonomic details and thus reduce the time involved. Careful measurements are often required in plankton identification and the records of such measurements should be entered on the drawings. Drawings need not be on a large scale, in fact, for many purposes they may be contained in the area of a 3 × 5-in. card In addition, the record should contain supplementary notes on salient taxonomic features not readily represented in drawings, such as color, behavior, and environmental relations.

FORM 7

PLANKTON IDENTIFICATION RECORD

Genus

Species

Locality	*Date*	*Identified By*	*Remarks*

CATALOG In addition to the records described above, a qualitative card catalog will be found useful if substantial work is being done Such a catalog may be of a form somewhat like the one shown in Form 7 The ordinary 3 × 5 in. card is often a suitable size

PRESERVATION OF PLANKTON

In the past many methods of preserving plankton have been proposed, some of which are elaborate, time-consuming, and not suited to the needs of general plankton work It now appears that the more complicated methods have little or no advantage over the simpler ones discussed below and they are therefore omitted here It must be understood that suitability for *general plankton work* is the main concern of the following discussion of preservatives

FORMALIN A 5 per cent solution of commercial formalin, a good general killing and preserving fluid which tends to preserve some colors of plankters, in general, produces little shrinkage of tissues, preserves immediately and permanently if strength of solution is kept at proper level, is a powerful antiseptic, and is generally available and inexpensive It has disagreeable effects on operator, tends to dissolve calcareous materials unless used in *neutralized* forms, action is not uniform, producing in at least a few plankters such different effects as body-form distortion, severe contraction, loss of cilia or flagella, distortion of internal structures, change of color, and change in external structures such as pellicles and shells, and causes complete destruction of a few plankters (see p 269)

It is imperative that the strength of all formalin solutions be known before they are used, also that proper provision be made to insure against loss of strength by evaporation. Preserved plankton samples should be stored in a darkroom Confusion in the meaning of the terms *formalin* and *formaldehyde* must be avoided.

ALCOHOL Pure methyl alcohol, 80 per cent strength. Lacks disagreeable effects of formalin, is an excellent preservative, causes shrinkage of tissues, has a decolorizing effect, is not always a good fixative, plankton must be introduced directly into full strength since transfer through grades of ascending strength can be effected only in the case of net plankton and then only with some difficulty, is more expensive than formalin

Use of denatured alcohol should be avoided, denaturing chemicals may have deleterious effects upon plankters

Plankton concentrates should be introduced directly into the storage bottle containing alcohol of such strength that the addition of the concentrate will still leave the preservative strong enough for permanent storage.

FORMOL-ALCOHOL. 5 per cent formalin added to 70 per cent alcohol, equal parts. An excellent fluid for general preservation.

Quantitative Methods

SAMPLING PROGRAMS

Reconnaissance Work. For preliminary or exploratory work, sampling does not necessarily require more than one or two stations, preferably located remote from shore. A generous amount of water should be taken if the sample is to be reasonably representative.

Comprehensive Survey. If a dependable measure of the plankton of any water is desired, the sampling program must be planned with great care, particularly if the lake or stream is of larger size and diversified. No set rules of procedure can be formulated. Each body of water presents its own circumstances on which the details of the sampling program must be based. In small lakes with regular shore lines and uniform bottom configuration, one station near the middle or in the deepest region may yield material representative of the whole lake provided collecting procedures are adequate.

Large, diversified lakes can seldom if ever be adequately sampled from one station and the number and position of required stations must be determined by the features of each lake concerned. Careful consideration must be given to those influences which produce diversity in the plankton distribution. No set rules can be laid down which apply equally in all lakes. However, these suggestions will help in planning such a program.

1. Never depend upon one sampling station.

2. Consider carefully the possible necessity of having at least one sampling station: (a) opposite sizable inflowing and outflowing streams, (b) in each horizontal flowage area, (c) at deepest region, if only one "deep" is present, at each submerged depression if more than one, (d) in partly enclosed bays and coves, (e) over extensive shallow areas, (f) in vicinity of protected shores, (g) in vicinity of exposed shores, (h) behind large islands; (i) behind large peninsulas, (j) in vicinity of marsh or swamp shores.

3. Consider desirability of selecting stations along significantly placed transects.

4. Consider possibility of adequate sampling by strictly random collections in chance positions scattered over all open water.

The number of sampling stations must not only be chosen to meet the demands of the water examined but also must be kept within limits of practicability. An idealized program might involve so many stations that plankton materials so secured would far outrun the ability of the operator to make proper use of them, also it might be made to exceed the general accuracy of the whole method.

SEASONAL SAMPLING If a true measure of plankton production in any body of water is to be secured, the sampling program must be extended to cover, at regular and significant intervals, all seasons of the year. Only in this way can the well-known and often wide fluctuations of the plankton crop be taken into account. Intervals between sampling must be so chosen that significant variations are not missed. In some programs, practicality may force the use of one-month intervals, but in some waters a truer picture may depend upon the use of two-week intervals Sampling intervals must be so chosen that particularly significant events are properly provided for, as for example, the seasonal highs and lows of plankton production, the overturns, intervals between broods of plankters, and the changing conditions under permanent ice cover

DURATION OF SAMPLING Since plankton production may fluctuate markedly from year to year, no dependable appraisal of the productivity of a body of water can be obtained unless the sampling program is extended over more than one year

QUANTITY OF WATER PER SAMPLE In sampling at any one station, sufficient water must be secured to insure a plankton concentrate truly representative of that situation Here, again, no fixed rule can be followed. Obviously in plankton-poor waters a much larger quantity must be used than in plankton-rich waters, also the same is true for the plankton-poor and plankton-rich seasons of the year in the same water. The operator must use his judgment Trial collections may be necessary in order to plan dependable sampling. Summer collections of net plankton in the average larger inland lake of the Great Lakes region should be based upon not less than 25 l per sample, preferably more Experience has shown that 75 l. usually provides satisfactory concentrates during the seasonal lows of plankton production and 3 l. may provide satisfactory concentrates of nannoplankton secured by the high-speed centrifuge during the same periods During seasons of plankton maxima, the amounts may be reduced In lakes of high plankton production, smaller amounts are more satisfactory

VERTICAL SAMPLING. Much depends upon a proper vertical sampling program. The depth levels at which samples are taken must be chosen in accordance with the circumstances which prevail at the particular locality sampled. Since these circumstances differ greatly in different situations and vary from time to time within the same water, no fixed set of rules for sampling procedures can be laid down The most satisfactory guide to a vertical sampling program on any particular date of collection is a set of physicochemical records made just prior to the proposed sampling A vertical series of temperatures, dissolved oxygen, pH, and free CO_2 records will usually give the necessary clues to the requirements for a plankton

series The following recommendations are likely to apply in general and serve as a framework for necessary modifications and extensions.

In temperate lakes of the *first* and *second orders*, samples should be taken at no fewer positions than the following ones during open season surface, middle of epilimnion, lower region of epilimnion, top, middle, and bottom of thermocline, and top, middle and bottom of hypolimnion. Under permanent ice cover this sampling program must be considerably modified.

In temperate lakes of the *third order* the minimum number of samples in a vertical series should be as follows surface, midway between surface and bottom, and just above bottom

The distribution of certain plankters in concentration zones is a possibility which must be taken into account in sampling Such concentrations may be thick enough to make it reasonably certain that almost any sampling program would include them However, some concentration zones are so thin that they may be missed entirely if the sampling levels are too far apart. The position of concentration zones differs in various lakes and with the seasons, therefore, no definite directions for locating them can be proposed. However, the possibility of their occurrence must not be overlooked

Day and Night Sampling Sampling carried on exclusively during the day may fail to yield a true picture of the plankton for two reasons, namely, the effects of diurnal movements of certain plankters and avoidance reaction

The various kinds of diurnal movements (Welch, 1935) result in vertical shiftings of populations or parts of populations from one region to another. Surface waters may teem with certain plankters during most of the night but the same plankters may disappear into deeper water or, in some instances, even into the bottom mud with the onset of day. During the day certain plankters may be distributed deeper in the water and in narrow concentration zones which might be missed entirely if sampling levels are too far apart.

Ricker (1938) and others claim that during the day and in the illuminated waters certain Entomostraca have the ability to see and avoid plankton samplers, resulting in a loss of a portion of the population. Sampling at night is recommended by these workers as a means of avoiding this error Knowledge concerning this behavior is still too meager to warrant definite statements as to its extent, but the possibility of this error should not be overlooked.

SAMPLING PROCEDURES

The following procedures are satisfactory for general purposes and may also serve as a guide to the operation of modified programs

Sampler-and-Plankton Net Procedure

SUITABILITY. The sampler-and-plankton net procedure is suitable for most quantitative purposes In addition to collection of net plankton, means are also provided for securing nannoplankton

EQUIPMENT Plankton net (p 239) containing No 20 or No 25 silk bolting cloth, 2 or more milk cans (5 or 10 gal), with known capacity and graduation marks on inside of can, one 5-gal milk can full of tap water, two 1-pt. dippers, field kit containing set of wide-mouth 250-cc. capacity glass bottles for receiving plankton concentrates, each bottle having a serial identification number and containing 5 cc of strong formalin, one 3-l capacity Kemmerer sampler (p 199) or some similar type of sampler, 1 graduated line, or a line and some form of rope meter, 1 brass messenger, 1 meter stick, tie-on cords, record forms, field kit containing set of 1-l capacity bottles, each with serial identification number, 3 ordinary buckets

Procedure

On arrival at selected station, anchor boat, and proceed as follows

1. Suspend plankton net in neck of milk can with canvas sleeve erect and opening upward, attach one end of 5- to 6-ft tie-on cord to ring at top of plankton net and other end to some convenient object on hull of boat, place can and included net in convenient place

2 Put messenger on graduated line, thread zero end of line through sampler and fasten securely Tie other end of line to convenient object on hull of boat

3 Set sampler in open form and, with messenger in hand, lower sampler into water to desired depth as measured on graduated line or by rope meter, release messenger and when sampler has closed, bring to surface, lift entirely out of water by use of line, dash a dipper of tap water over outside to wash off any adhering plankters from other levels

4 Insert lower end of sampler into uppermost sleeve of plankton net and release sampler load into net either by rotating lower valve until it loosens or by judicious endwise pushing of central rod of sampler

5. Reset sampler and repeat operation Keep careful record of number of sampler loads put through net, watch water level in milk can until it becomes filled with strained water, if more than one container is needed, transfer plankton net to another can and proceed as before

6. At conclusion of sampling, read level of strained water in each can by means of graduated marks on inside and put on record; also for purposes of further check, insert meter stick vertically into can and measure depth of strained water, and record result. Record identification numbers of cans used at each station and at each depth level.

7. Lift plankton net vertically in mouth of can and allow contained water to drain into can until water level in net drops below upper rim of plankton bucket. Detach plankton bucket, set lower end into open neck of concentrate bottle, and remove bucket plunger, delivering contents of bucket into bottle Replace plunger and reattach bucket to net, with dipper, dash wash water all around inside of net to wash down adhering plankters, at same time grasping metal parts of bucket and giving it a rotary motion to wash its inner surface Drain as before, this time discarding wash water, remove bucket from net, and deliver collected material into concentrate bottle, record number of bottle used.

8 Wash plankton bucket in pail containing tap water, also, with hand over lower open end of headpiece, dash tap water into inside of net and release by removing hand in order to eliminate any plankters which possibly remained after first washing, reattach bucket to net

9 Stir water in milk cans and fill one or more liter bottles with water from each different station or level sampled for subsequent nannoplankton measurements, stopper carefully and make proper records, remaining strained water may be discarded

General Considerations

a Telescoping surfaces of plankton bucket and headpiece should be kept lubricated with a minimal amount of petrolatum or some similar substance. From time to time these surfaces should be cleaned with a rag saturated with gasoline, dried, and relubricated. Excess lubricant may easily find its way onto the silk bolting cloth.

b In all operations, avoid touching silk bolting cloth with hands, sampler, or other objects

c. Washing of net and bucket should be done inside the boat. Washing over the side of the boat in lake water is poor technique, also there is the hazard of loss of net or its detachable parts.

d Before sampling begins, the operator must make certain that the silk of the net is in good condition in every respect. In an older net close scrutiny is required since small breaks may appear under the best of handling.

e Cans containing water which has been strained through the plankton net should be capped and inverted four or five times before filling liter bottles for nannoplankton measurement

Plankton Trap Procedure

Suitability The plankton trap procedure is suitable for most quantitative work, provided net plankton alone is adequate Nannoplankton from the same sample cannot be secured

Equipment Plankton trap, complete with attached plankton net of

No 20 or No 25 silk bolting cloth, crane or hoist suitable for attachment to boat to lift plankton trap, large milk can or similar receptacle containing tap water, two 1-pt. dippers, field kit containing set of wide-mouth 250-cc. glass bottles for receiving plankton concentrate, each bottle with serial identification number and containing 5 cc of strong formalin, 1 graduated line, or plain line or cable if hoist is equipped with rope meter, brass messenger, record forms, 2 pails

Procedure

On arrival at selected station, anchor boat and proceed as follows

1 Install hoist in convenient position, thread messenger on line, attach line securely to plankton trap, set lids of trap in open position

2 Swing arm of hoist over water and in such position that trap will not make contact with boat, lower trap slowly into water, control its sinking so that vertical descent is made certain, lower to desired depth Drop messenger and permit sufficient time to elapse for messenger to release lids of trap, lift slowly to surface, lift gently out of water and allow trapped water to drain out through net until level is just below upper rim of plankton bucket

3 Detach plankton bucket from net, set lower end of bucket into open neck of concentrate bottle, remove plunger, delivering contents of bucket into bottle Replace plunger and reattach bucket to net, pull upper trap lid into open position, with dipper, dash tap water all around inside of both trap box and net to wash down any adhering plankters, at same time grasping bucket by its metal parts and giving it a rotary motion to wash its inner surface more thoroughly Drain as before, discarding tap water which drains through, remove bucket from net, deliver collected material into same concentrate bottle, record all essential data

4. Wash bucket in pail containing tap water, also dip net into tap water, reattach bucket to net and proceed to next sample.

General Considerations

a A plankton trap must be kept in a specially built field case during transportation to avoid damage. On return to the laboratory the trap, net and case should be dried in open air but not in direct sunlight.

b A plankton trap may be used without a hoist by the hand-over-hand method, but ordinarily this is not a satisfactory procedure because of the unwieldiness of the trap and the risk of damage

c Ordinarily the field party should be composed of two persons although, with the right kind of a hoist and accessories, one person can make collections with the plankton trap In the absence of a suitable hoist, it is ordinarily impracticable for one operator to work alone

d. Before going into the field the trap should be inspected thoroughly

for good condition and operation. The grooves in which the lids slide may, at times, require cleaning.

e. If traps of the larger capacities are used, it may happen that one sample will yield a suitable concentrate. However, if more than one sample from the same place or level is required and the resulting concentrate is too dilute, reconcentration of the accumulated concentrates may be desirable, but this must be done before the formalin is introduced.

Net Coefficients

Formerly, when collection of net plankton by hauling nets through water was a more common practice, much attention was given to the correction of certain errors involved. It was realized that the degree to which a net, drawn through water, filters that entire column of water represented by the size of the net aperture and the distance through which the haul is made, depends upon certain factors such as speed of haul, size of mesh, age of net, and clogging of net. Even under the best operating conditions, a certain amount of overspill occurs at the net aperture with the result that not all of the water passes through it and the plankton catch is less than it should be. The ratio of the actual catch to the catch that would have been taken had all of the water of the column passed through the net is known as the *net coefficient* and must be determined experimentally for each individual net at the various proposed speeds of operation. The ratio so secured is used in applying a correction to actual catches. For example, if for a certain net operated at a given speed the ratio $\frac{\text{total plankton in water}}{\text{total plankton caught}} = 1.3$ (net coefficient), then the plankton actually caught must be multiplied by 1.3 if the final result is to approximate the total plankton in the water column.

Since of recent years plankton nets are commonly used only for straining operations in which definitely measured quantities of plankton-bearing water are delivered through the net, and since nets drawn in the water, such as Clarke's net, may be equipped with meters which measure the amount of water actually entering the net, the determination of net coefficients is a matter of decreasing importance. However, the closing net, described on pp. 246–249, is still a useful device for some purposes and if used for precise quantitative work, the efficiency of the net should be tested and coefficients determined. Various methods of determining net coefficients have been developed but for common purposes the following one will probably be convenient and adequate for the closing net. If a plankton trap (p. 242), having a net of same mesh and age as the closing net is available, make catches at meter or half-meter intervals across the same stratum through which the closing net is to be hauled, from these trap catches compute the total plankton content of the whole water column

having transverse dimensions of plankton trap, from this information, compute the plankton content of the column having the transverse area of the closing-net aperture, compare this result with the plankton catch made by drawing the closing net through selected stratum This procedure will give a fair index of the efficiency of the net If a plankton trap is not available, the same procedure may be followed, using a sampler, such as a Kemmerer sampler, bringing samples to the surface and passing them through the same closing net as used for the haul.

Analyses of Plankton Concentrates

Choice of a procedure for analyzing plankton concentrates quantitatively must be made in accordance with the use to which the results are to be put The various methods may be grouped under three main headings, viz, numerical methods, volumetric methods, and gravimetric methods

NUMERICAL METHODS

Under the designation of Numerical Methods are grouped those quantitative methods which result in measures of plankton expressed in terms of *numbers of plankters* or *numbers of units of plankters*, or both, per unit volume of natural water

Equipment

All numerical methods require the use of suitable optical equipment.

Compound Microscopes. A good grade compound microscope is a necessity and should be equipped at least with a draw tube, one 10× ocular and one 16-mm (10×) objective More extensive accessories may be necessary, such as (a) other oculars and objectives of higher and lower magnification, (b) substage condenser, with iris diaphragm, (c) mechanical stage, and (d) graduated fine-adjustment screw

Binocular Microscopes For certain kinds of plankton work a binocular microscope is useful since it provides the most satisfactory means of making total counts of large plankters within a whole counting cell The optical equipment of such an instrument should include 10× oculars, one 40-mm objective, and one 25-mm objective. Other optical combinations may be used but because of the small size of the largest plankters it is likely that ordinary needs will fall near the combinations indicated above A mechanical stage is often desirable

Ocular Micrometer Some type of ocular micrometer adapted for plankton counting is required. Such a device may be of various forms but the most satisfactory one is the Whipple micrometer (Fig 77) Its rulings are engraved on a disk of thin clear glass the diameter of which is such that it will just fit into the interior of an ocular. The dimensions of the

large square are such that with a certain combination of objective, ocular, and draw-tube length the area enclosed on the microscope stage is exactly 1 sq. mm. (1 mm on each side) Such micrometers may be in the form of a simple glass disk, or they may be rimmed with metal for greater protection against breakage

COUNTING CELL A counting cell suitable for ordinary purposes is designed for the examination of plankton concentrates on the stage of a microscope It may be constructed in many forms depending upon the character of work to be performed. The type commonly used is the Sedgwick-Rafter cell consisting of a brass rectangle, 50 × 20 × 1 mm.

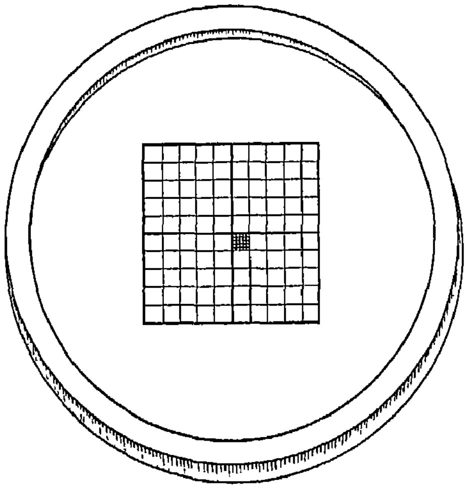


FIG 77 Whipple ocular micrometer.

sealed to an ordinary 1 × 3-in. glass microscope slide (Fig. 78). It encloses an area of 1000 sq mm, has a depth of 1 mm, and has a capacity of exactly 1 cc. A rectangular cover glass, large enough to cover the whole cell, is required

The principal objection to the Sedgwick-Rafter counting cell arises from the fact that its thickness prevents the use of higher magnifications of the microscope Very shallow counting cells which permit the use of high-power objectives may be made by carefully constructing from very thin sheet brass a rectangle similar in length and width to the Sedgwick-Rafter cell and sealing it to a glass slide Similar counting cells may be made by cutting four strips of very thin glass and sealing them on a glass slide in the form of a rectangle Canada balsam is a suitable sealing material.

The form of a counting cell may be immaterial A circular cell is easily made and quite satisfactory The depth and diameter may be made to suit the desires of the operator. For some purposes a long narrow counting cell

has advantages, especially when the larger plankters are counted under a binocular microscope and the entire width of the cell is within the diameter of the field of view.

PIPETS. Samples of plankton concentrates are usually transferred from the concentrate bottle to counting cells or to other receptacles by means of pipets. These pipets must be of such form that the samples taken are truly representative of the concentrate as a whole. If ordinary laboratory pipets are to be used, the operator must make certain that the intake apertures are several times greater in diameter than the longest dimension of the largest plankter thus insuring against the possibility that the pipet

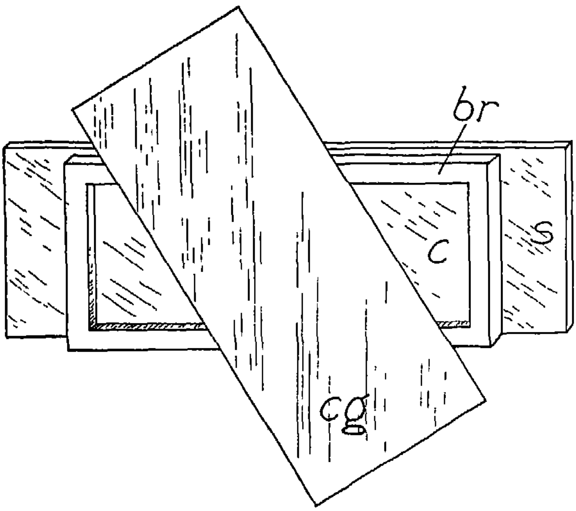


FIG 78 Sedgwick-Rafter counting cell (*br*) Brass rectangle (*c*) Cell enclosed by brass rectangle. (*cg*) Cover glass (*s*) Glass slide to which rectangle is sealed.

is exercising any selection of organisms when concentrate is drawn into it. Usually the safest procedure is to cut off the tapered tips of pipets, leaving a large opening. Such a pipet should be tied with a string to the concentrate bottle in which it is to be used, thus safeguarding against the possibility of mixture of pipets among the different concentrate bottles.

Special devices for accurate quantitative sampling of plankton concentrates have been devised The well-known Hensen-Stempel pipet (Fig. 79) consists of a piston, composed of alternate layers of metal and cork held tightly together, fitted into a strong glass tube To the lower end of the piston is attached a spool-shaped piece of metal, the flanges of which fit closely the inside surface of the glass tube. When pulled into the tube, the spool forms with its walls a closed space of known volume. The metal

spool is removable and others of different size may be substituted. If the cork in the piston has become dry from long storage, it should be soaked in water for several hours before it is put into use To operate, push piston handle down, exposing spool to outside, thrust lower end of pipet deep into the thoroughly mixed plankton concentrate, pull handle up until spool is entirely within walls of glass tube thus enclosing sample, then lift pipet from concentrate, carry to its destination, and discharge by pushing down handle until spool is again exposed The principal virtue of the Hensen-Stempel pipet is its convenience and its speed in taking samples

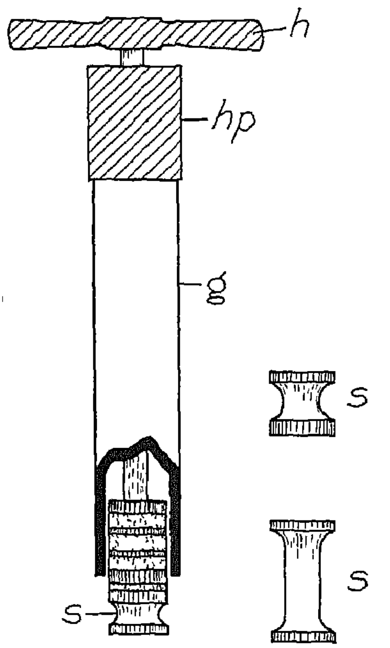


FIG. 79 Hensen-Stempel pipet for quantitative sampling of plankton concentrates Lower end of pipet shown is cut away to expose piston composed of alternate layers of cork and brass, crosshatched parts are brass, stippled parts are cork disks (*g*) Heavy glass tube. (*h*) Handle. (*hp*) Brass headpiece (*s*) Metal spool, detachable, determines size of sample, three sizes are shown in figure.

Calibration of Ocular Micrometer

Irrespective of type of construction, every ocular micrometer must be calibrated. Also it should never be assumed that calibration values worked out for one individual micrometer can, without verification, be applied to another. Details of calibration may differ for micrometers of different forms, but fundamentally the procedures are similar

WHIPPLE OCULAR MICROMETER Since the Whipple ocular micrometer is the one in most common use and is recommended for general purposes, its calibration procedure will be described in detail It will also serve as a basis for the calibration of other micrometers

Procedure

1. Select compound microscope and accessory equipment, clean thoroughly all optical parts, record identification numbers of microscope, objectives and oculars

2 Select Whipple ocular micrometer, record its identification number, clean thoroughly.

3 Remove 10X ocular from microscope, unscrew eye lens (lens near-

est eye of observer), insert micrometer into ocular, ruling side downward, and make certain that micrometer comes to rest flat on shelf extending from side of ocular about midway of its length; replace eye lens in ocular, replace ocular in microscope and examine for clarity of micrometer rulings. These rulings must be in clear, clean-cut focus, if not, try different positions of micrometer in ocular until clearly defined image of rulings is secured.

4. Select suitable stage micrometer with rulings of known value (values usually indicated on one end of slide), compare rulings with some dependable standard as check for accuracy, rulings with values of 0.1 and 0.01 mm. are usually suitable, place stage micrometer on stage of microscope, turn on 16-mm. objective, and focus on stage micrometer rulings for as clear an image as possible. Since rulings are on glass, careful adjustment of light is a necessity.

5. Superimpose ocular micrometer rulings upon those of stage micrometer and orient so that one side of former rests across scale of latter, one end coinciding exactly with one line on stage micrometer, pull out draw tube of microscope barrel, observing effect of same, until one side of ocular micrometer square becomes exactly 1 mm. in length, turn ocular 90° and test length of adjacent side of square in same way, repeat similarly for other sides, by means of graduated scale on side of draw tube, ascertain tube length used and make permanent record of same. In similar way check accuracy and determine value of subdivisions within large square of ocular micrometer.

6. If ocular micrometer has been properly constructed, and if the conditions mentioned above have been met, then area enclosed by large square = 1 sq. mm. on stage, that enclosed by each of 100 interior squares = 0.01 sq. mm., that enclosed by one of smallest squares = 0.0004 sq. mm. One side of smallest square has length of 0.02 mm.

7. Calibrate other combinations of objectives and oculars in similar way.

8. Record all data in table constructed similar to Form 8.

General Considerations

a. Occasionally the operator may find an ocular in which the interior supporting ledge is not properly placed, consequently, there is no position for the ocular micrometer in which the rulings are in clear view. In such instance the substitution of another ocular of the same grade is the quickest solution of the difficulty.

b. Some ocular micrometers are rimmed with brass or other metal as protection against breakage. In such rims the glass may be so mounted that one side is deeper than the other. Commonly the deeper side should be uppermost in the ocular.

c. Close-fitting, metal-rimmed ocular micrometers sometimes are difficult to introduce into, or remove from, the ocular because of a tendency to jam. Gentle shaking, jarring on palm of hand, judicious use of a rubber-tipped probe, or similar treatment will correct the trouble Use of force must be avoided.

d In the calibration of the ocular micrometer used with different optical combinations of oculars and objectives, it is possible, and under some circumstances more convenient, to find a draw-tube length for each optical combination which will make some lines on both ocular and stage micrometers coincide exactly However, this may necessitate a different tube length for each combination, thus leading to errors through the operator's forgetting to change tube length with changes of optical parts Ordinarily it is safer to calibrate all optical combinations on the basis of one tube length

e If the large square of the ocular micrometer is to be used as a whole, the operator must determine at the outset whether the entire square falls within the field of view. If two adjacent corners are slightly cut off, gentle tapping on the side of the ocular may shift the micrometer on its supporting ledge and bring all corners within view, if all four corners are cut off, or if large amounts of two corners are cut off, there is no remedy except to use an ocular of different construction However, cut-off corners will not interfere with the use of the smaller squares of the micrometer

f Dimness of ocular micrometer rulings on one side results from failure of the micrometer to rest flat on the supporting ledge, or from a defective installation of the supporting ledge in the ocular

FORM 8

Microscope No	*Ocular Micrometer No*	*Stage Micrometer No*	*Ocular*	*Objective*	*Tube Length*	*Value of Counting Unit*

Survey Count

In the *survey count* the large net plankters, such as the Microcrustacea, rotifers, and others of similar size which can be readily seen and identified under very low magnifications of the microscope, are counted in the entire counting cell.

SUITABILITY The survey count, as commonly used, is suitable (a) when only an enumeration of the largest plankters is needed, (b) when in the interests of economy of time and energy the largest plankters are counted in the entire counting cell, leaving all smaller ones to be counted by the application of another more suitable method, and (c) when some of the largest plankters occur in such sparse numbers that a much larger quantity of concentrate must be examined in order to secure a more adequate measure of them

EQUIPMENT. Compound microscope with low-power objective and ocular, or binocular microscope with assortment of objectives and oculars, Sedgwick-Rafter counting cell, pipets for transferring concentrate, thin sheet of translucent paper, cover glass, or other similar material, ruled in squares Mechanical stage and hand tally are convenient but not required

Procedure

1. By means of appropriate type of calipers, measure dimensions of counting cell very accurately and compute its capacity.

2 By use of graduate of suitable size and graduation, measure total volume of original plankton concentrate, enter on record form

3 Fill counting cell with tap water and test for leakage, empty cell and dry completely.

4 Place counting cell on level surface, lay cover glass diagonally across middle of counting cell (Fig. 78) leaving uncovered area at each end

5 Make certain that concentrate bottle is securely closed or stoppered, take concentrate bottle in hand, placing thumb over stopper or cover to insure that it stays in place, invert concentrate bottle slowly and gently at least seven times to provide thorough mixing, open concentrate bottle immediately and with pipet secure sample before any settling of plankters occurs, transfer pipet sample immediately to counting cell, introducing into one of open ends a quantity sufficient to slightly more than fill cell, return unused part of pipet sample to concentrate bottle

6 Keeping cover glass in contact with rim of counting cell, carefully swing it around until whole cell is covered, cutting off excess concentrate and leaving cell completely filled If air bubbles are enclosed within cell, whole procedure of filling must be repeated

7 Transfer counting cell to stage of microscope and examine If, as is likely, only a portion of cell is visible, slip under counting cell a sheet

of translucent paper, a large cover glass, or some similar object, ruled in squares of convenient size, thus dividing whole cell into recognizable areas; attach mechanical stage if available

8 Determine what plankters may be dependably counted in survey, begin at one end of counting cell and progressively count plankters in each of square areas. If survey includes only one kind of plankter, counting may be speedily recorded by hand tally if available, if not, use ordinary tally method on record sheet If survey includes several kinds of large plankters, count one kind at a time as just indicated, or if simultaneous counting of all selected plankters is desirable, use tally method on record sheet.

9. Examine as many different samples from concentrate bottle as practicality and desired precision of result require.

10. From averages of individual counts, compute total number of plankters in entire concentrate, then compute number per liter of original water as it occurred in nature.

Total Count

By *total count* is meant an enumeration of all plankters recognizable under the conditions of the examination without any attempt to distinguish between the different kinds

SUITABILITY. The total count is suitable for quantitative determinations of plankton in which the mere *number of individual* plankters is adequate It may be used (a) in making a count of all plankters, large or small, in the total concentrate or (b) in combination with the survey count in which instance the smaller plankters are counted It is commonly used for work with net plankton but if very thin counting cells are employed, counts of nannoplankton are possible

EQUIPMENT. Compound microscope with suitable series of oculars and objectives, counting cell, either standard Sedgwick-Rafter type or specially made thin cells; pipets for transferring concentrate; Whipple ocular micrometer, or similar type, record forms. A hand tally is a convenience and adds to the speed of counting

Procedure

1 With appropriate type of calipers measure carefully depth of counting cell.

2 Make careful measurement of volume of original plankton concentrate, enter on record form.

3 Fill counting cell with tap water and test for leakage; empty cell and dry completely.

4 Install micrometer in ocular and calibrate as described on p 282 After areal value of largest square has been determined, convert into cubic

unit by multiplying it by depth of counting cell Record value so computed.

5 Mix contents of concentrate bottle and fill counting cell as described on p 285, allow counting cell to stand for short time until organisms have settled, transfer cell to microscope

6 Select, at random, one area, wholly within cell and count included plankters according to following directions (a) count only plankters which were alive at time concentrate was killed, (b) ignore all kinds of debris, cast skins, fragments of plankters, and objects and organisms accidental to the concentrate, (c) count as *one plankter* each filament, colony, egg mass, partial colony or mass irrespective of size, (d) count each separate individual organism as one plankter, (e) in instance of plankter partly inside and partly outside counting square, estimate fractional part within square and so record, (f) counting fields which by chance of random selection contain no plankters must be counted as zero and included in computing averages, (g) any stage of life cycle of plankters must be counted when isolated from parent

7. Focus microscope through entire thickness of cell to make certain that all plankters are counted.

8 With eye removed from ocular, move counting cell any distance to new field and count as before, repeat until ten fields selected strictly at random have been counted Use of 2 different counting cells full of concentrate and 10 fields counted in each gives higher degree of accuracy.

9 From results so secured, compute number of plankters per liter of original lake or stream water by use of following formula

$$n = \frac{(a1000)c}{l}$$

in which n = number of plankters per liter of original water
a = average number plankters in all counts in counting unit of 1 cu mm capacity
c = volume of original concentrate in cc
l = volume of original water expressed in liters

If the survey method has been employed for the larger plankters of the same concentrate, then the total count may be computed from the following formula

$$n = \frac{wc}{l} + \frac{(a1000)c}{l}$$

in which w = the number of larger plankters enumerated in survey count in whole counting cell (1 cc), or average of all counts of whole counting cell (1 cc)

General Considerations

a Counting cells should be tested at all four corners for uniformity of depth, resealing of cells sometimes results in one side or one end being higher than the opposite one

b. Distribution of plankters in the counting cell is not, and cannot be, uniform, therefore, it may happen that counts of the various counting units differ considerably, hence the value of making a considerable number of counts

c No rule can be laid down concerning the number of random units to be counted in each cell The ten indicated above is commonly regarded as reasonably good practice; a larger number taken from more than one counting cell will result in increased accuracy.

d Sometimes it is desirable to make a preliminary examination of the concentrate to discover if the amount of dilution is favorable If a concentrate is so thick that counting is difficult, the test sample should all be returned to the concentrate bottle and tap or distilled water added until a desirable dilution has been produced, then the newly diluted concentrate must be remeasured for volume If a concentrate as taken from the field operations is found to be too dilute for satisfactory and dependable counting, it may be necessary to reduce the concentrate to a smaller volume by passing a portion of it through hard surface filter paper, returning the catch on the filter paper carefully to the other portion of the concentrate and remeasuring the new volume of the total concentrate

e Mixing of concentrate prior to counting must be done slowly and gently, rough treatment may result in damage to plankters

f The operator must not be misled by accidental attachment and other odd forms of relation of diverse plankters to one another in concentrates—results which come about from the very fact of concentration

g Ordinarily, it is regarded as impracticable to attempt to count bacteria in concentrates.

h Difficulties sometimes arise in positive discrimination between remains of plankters which were dead before the sample was collected and plankters which were alive at the moment of killing by preservative in the concentrate bottle. Ordinarily doubtful cases should not be counted.

i Objects so small as to be near the limit of vision may not be recognizable with certainty as plankters. It is usually necessary to ignore them.

j. When, for any purpose, it is desirable that a measure of the detritus be included, count the *masses* of detritus and list separately under that designation

k A hand tally adds to the speed and accuracy of counting, however, in using a tally, the estimation of fractional parts of plankters partly within the field must be done separately and then added into the total

l. If the microscope is equipped with a mechanical stage, the *zonal* method of counting may be substituted for the random unit-area method. The procedure is as follows Start at one end of counting cell and move cell by means of mechanical stage toward opposite end, counting plankters as they pass through ruled field of ocular micrometer, repeat until several such zones have been counted The dimensions of a zone will be the product of the length of the counting cell, its depth, and the length of one side of the ocular micrometer square That product multiplied by the number of zones will give the amount of concentrate actually examined. Zones may be made across the counting cell if desired.

m Final computation is facilitated if, by the addition of wash water (distilled water, tap water, or filtered water), the volume of the concentrate is made to be some exact multiple of 10, provided, of course, that the addition of more water will not produce too great a dilution

Differential Count

By *differential count* is meant the enumeration of some or all of the different kinds of plankters, distinguishing them qualitatively, counting and recording the numbers of individuals of each The extent to which the taxonomic subdivision is carried will depend upon the conditions and purpose of the study, and upon the experience of the operator in the recognition of species, genera, and other groups in the classification Ideally, such a count should involve identification to species, but depending upon circumstances, this may be impossible, or impracticable, or even unnecessary (p 268)

SUITABILITY AND EQUIPMENT Same as in the total count (p. 286)

Procedure

1. Follow procedures outlined in preceding section on *total count*, except that each different kind of plankter is counted separately.
2. Enter counts of each kind of plankter on record form by the tally method If only certain selected kinds of plankters are considered, counts may be made with a mechanical hand tally
3. Make calculations for each kind of plankter by means of formulas indicated in preceding section (p. 287) and express results in *number per liter.*

Limitations of Survey, Total, and Differential Counts

Results obtained by survey, total and differential counts are enumerations only in which no account is taken of great differences in size of plankters Because of the necessary use of counting cells having some depth, high magnification is precluded and the smallest of the nannoplankton can receive at best only very uncertain consideration. Precision of

these methods, under the best of conditions, probably cannot be expected to be better than about 90 per cent

Areal Standard-unit Method

The areal standard-unit method was devised originally by Whipple to provide a quantitative means of measuring plankton in which the size of the individual plankters is considered. Thus one of the obvious limita-

FORM 9

PLANKTON RECORDS

Locality	Depth	Records By
Date	Bottle No	Apparatus
Time	Lake Water	Corrections
Wind	Concentrate	Counting Unit
Sky		

Organisms	1	2	3	4	5	6	7	8	9	10	Total	Av
Totals												

Number per

tions of the survey, total, and differential counts is largely eliminated The areal standard-unit method, when properly employed, has commendable features and is widely used It is based upon the principle that since most organisms in a counting cell rest in such a way that their greatest surface area is in a horizontal position, a measure of that *area* of each plankter visible to the operator gives a close estimate of its volume. The measurement is, then, actually one of area although it is used as an index to volume In order that such a value may be in usable form, an *areal standard unit* is employed in terms of which all measurements are expressed. This standard unit has an area of 0 0004 sq mm. (400 square microns) enclosed within a square each side of which has a length of 0.02 mm. (20 microns). The Whipple ocular micrometer was designed specifically to meet the requirements of this method

SUITABILITY. The areal standard-unit method probably finds its most convenient use when applied to net plankton and when employed with that combination of objective, ocular and tube length on the miscroscope which provides that one side of the large square of the ocular micrometer exactly covers 1 mm on the stage However, its use may be extended to higher magnifications and very thin counting cells by reevaluating the ocular micrometer for each optical combination in terms of the areal standard-unit dimensions as given above

EQUIPMENT. Whipple ocular micrometer, compound microscope with 10× ocular and 16-mm objective, other objectives and oculars as desired; Sedgwick-Rafter counting cell, or equivalent, or thinner cells if desired; pipets for transferring plankton concentrate.

Procedure

1. Introduce Whipple micrometer into 10× ocular of microscope, test for clear visibility of micrometer rulings, set microscope with 16-mm. objective and proper tube length (see p. 282 for directions for calibrating micrometer) so that each side of large square in ocular micrometer exactly covers 1 mm on stage

2. Measure dimensions of counting cell as described on p 285, fill counting cell with concentrate following directions given on p 285

3. With microscope set as indicated above, each of series of 25 smallest squares ruled near middle of large square (squares of third order) has area exactly representing one *standard unit* (0 0004 sq mm) Since all other squares (squares of first order, squares of second order) are multiples of the standard unit, the eye of operator, with practice, can easily divide sides of squares of second order into fifths

4 Select one plankter wholly within large squares; determine, by means of squares or partial squares which it crosses, length and breadth of selected plankter in terms of length of one side of standard unit (0 02

mm), multiply number of units of length by number of units of width and result will be in *standard units*. Proceed in same fashion with all other plankters within large square. In instance of plankters partly within and partly outside square determine number of standard units only in those portions within square.

5. Proceed with nine other counting areas (or some larger number) selected at random within counting cell, on basis of averages of total count and differential counts, compute number of *areal standard units* in 1 l. of original water.

General Considerations

a It will be convenient to designate 0 02 mm (length of one side of areal standard unit) as one *linear unit* Thus, for example, a certain filament can be referred to as 20 linear units long and 0.6 linear unit wide

b The efficiency of this method depends much upon careful practice The eye rapidly gains accuracy and, with practice, speed in estimating linear dimensions and areas in terms of the standard unit, a procedure which at first seems slow, tedious, and uncertain, soon develops into an effective one

c. It will usually be desirable to combine simultaneously the total count, the differential count, and the areal standard-unit count in the same procedure, thus yielding results which supplement each other

d. Some plankters, e.g., certain diatoms, are so constant in size that they may be counted individually and then converted to standard units by multiplying the total number of individuals counted by a constant representing the size of the individual Some filamentous plankters have very constant diameters, hence counting is faciliated by determining the length in linear units of the individual filaments and then multiplying by the number representing the common diameter

Cubic Standard-unit Method

The method of measuring plankters quantitatively by the use of a *cubic unit* is in some respects the most desirable one of the various enumeration methods due to the fact that the results are actually volumetric It is essentially an extension of the areal standard-unit method in which the third dimension of plankters is measured and results expressed in terms of a *cubic unit* whose size is 0.000008 cu mm. (8000 cubic microns) and the length of one side of which is 0 02 mm This unit, then, is merely the areal unit converted into a cubic unit by multiplying it by the length of one side of the cube, namely, 0 02 mm

SUITABILITY The suitability of the cubic standard unit method is very similar to that of the areal standard-unit method (p 291)

EQUIPMENT. The equipment needed is the same as that required for the

areal standard-unit method, except that if the third dimension is to be measured directly, the compound microscope must be equipped with a graduated micrometer head on the fine adjustment so that the third dimension (thickness) may be measured by determining the distance through which the microscope tube moves in focusing from the uppermost to the lowermost surfaces of a plankter The value of the change in vertical distance produced by the rotation of the fine adjustment screw is commonly supplied by the makers of the microscope. If the value is not known, it will be necessary to calibrate the screw

Procedure

1 Set up microscope and fill plankton counting cell as described previously for areal standard-unit method (p 291)

2 Before beginning count, decide which one, or combination, of the following ways of obtaining value of third dimension is most practical and suitable for work in hand

(a) Focus carefully on topmost and bottommost surfaces of plankters and determine thickness from vertical distance through which objective moved by reading on graduated fine-adjustment screw head. If plankter is too opaque to permit focus on bottom with certainty, focus on top, then on periphery, and regard vertical distance through which objective moved as one-half the thickness of plankter

(b) Note whether form of plankter approaches that of a sphere, a cylinder, or an ellipsoid, if so, use diameter as third dimension If form approaches cube, use linear measurement as third dimension This method requires no direct measurement of thickness

(c) Measure directly thickness of several individuals of each species and compute average, use this average for all individuals of that species subsequently counted

3. Proceed to counting of 10 or more fields selected at random Also simultaneously keep record of number of individuals as in total differential count From average of all counts, compute total cubic units in total concentrate, then compute number of cubic units of plankton per liter of original water in usual way

4 Record results in cubic standard units If for any reason it should be preferable to express results in parts per million by volume, divide number of cubic standard units by 125

LIMITATIONS Since the cubic standard-unit method involves measurement or estimation of three dimensions, the work is necessarily slower than in the areal standard-unit method, also much greater experience on the part of the operator is required if results are to be reliable Even in the hands of an experienced operator, any speeding up of the work may lead to errors

General Considerations

a. The chart (Fig. 80) facilitates the calculation of cubic units from linear dimensions In this chart the spherical and cubic volumes are obtained directly by the use of any measured diameter or side Cylindrical volumes are secured by applying the diameter of the circular cross section to the chart as linear standard units, then reading the corresponding cubic standard-units value, and multiplying it by the length of the cell or filament in linear units. Ellipsoidal volumes are obtained by applying the third diameter of the plankter and multiplying the value so determined by the product of the long and short diameters of the elliptical section

b As an aid to the computation of cubic standard units, use may be made of a table commonly included in engineers' handbooks from which may be read directly the area of a circle, the volume of a sphere, and the volume of a cube, from a graded series of diameter values.

c. When in some kinds of work a volumetric measure of the amorphous material is desirable, volumes in terms of cubic standard units

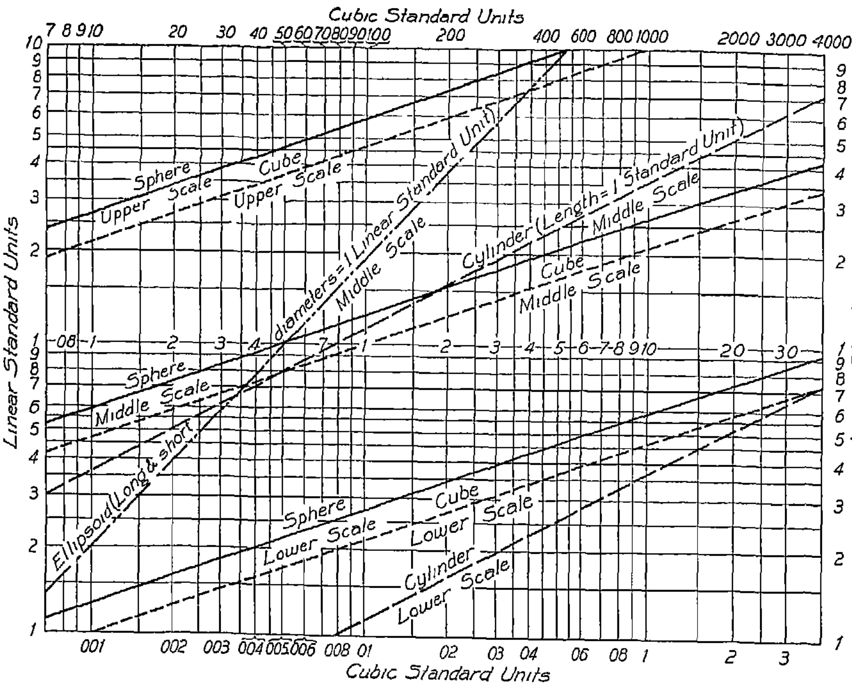


FIG 80 Chart for the determination of cubic standard units from linear dimensions of organisms (Reprinted by permission from "The Microscopy of Drinking Water," by Whipple, Fair, and Whipple, published by John Wiley and Sons, Inc) (Redrawn.)

may be secured by estimation of the number of units in each particle

d A convenient form of keeping simultaneous records of both total differential count and volumetric count is the use of a common fraction in which the numerator represents the number of individual plankters while the denominator represents the number of volumetric standard units

e. For work of this kind a specially prepared plankton-count form with a complete set of headings and ruled columns should be used for all records.

GRAVIMETRIC METHOD

Gravimetric methods are concerned with measurement of plankton in terms of units of weight per selected quantity of plankton-bearing water The procedures described here are based upon those developed by Birge and Juday

SUITABILITY This method may be applied to net plankton, nanno-plankton, or both. It is also suitable for plankton concentrates irrespective of the method of collection, provided that all of the necessary collection data are available.

EQUIPMENT Plankton centrifuge and accessories (p 256), platinum dish with capacity of 8 cc., electric constant-temperature oven maintaining temperature at 60° C; analytical balance sensitive to 0 0001 g, electric furnace which can maintain a temperature of 600° C

Procedure

1 Secure centrifuge concentrate as indicated on pp 258–259 If plankton is abundant, 1-l samples will be adequate, if plankton is scarce it may be necessary to centrifuge two or more liters of water, measure volume of concentrate (should not exceed 8 cc).

2 Place concentrate in platinum dish; put in electric oven maintaining controlled temperature at 60° C, leave in oven until all water is evaporated (about 24 hrs).

3 Weigh dish and contents, transfer to electric furnace maintaining temperature at about 600° C.; leave in furnace for 30 min.

4. Weigh dish and contents, result of second weighing subtracted from that of first weighing gives *gross loss* due to ignition.

5. To correct for organic matter in solution in that lake water included in the concentrate, run a blank consisting of same amount of centrifuged lake water at same time and in same way as plankton sample. Subtract weight of furnace-incinerated sample of blank from weight of oven-dried condition of same sample, difference represents organic matter in lake water and constitutes correction to be subtracted from *gross loss* mentioned in paragraph 4 above

6 Compute amount of organic matter in original water, expressing results in milligrams per liter.

General Considerations

a It must be understood that a centrifuge concentrate includes all of the various materials in suspension in the water, such as silt, wind-blown materials from shore, dead and disintegrating animal and plant remains in finely divided condition, and exuviae Therefore for this and certain other reasons it is not correct to assume that a centrifuge concentrate is a measure of the living plankton alone No satisfactory method of separating the living plankton from these other suspended materials has been devised The magnitude of this error will vary greatly depending upon circumstances, in certain clean waters it may be so low as to be practically negligible for most purposes, in other waters which are heavily laden with suspended matter, it may be so high as to render the method useless Preliminary examination and the exercise of good judgment will determine whether this method can be expected to provide useful results.

b The effectiveness of the first run of a sample through the centrifuge has been mentioned on p 259. If the sample should contain appreciable amounts of *Aphanizomenon*, only about one-half of this plankter will be obtained in the first run, but in the second run practically all is secured

c. If for any reason it is desirable to express the amount of plankton as *wet weight*, evaporation is stopped at the end of step No 2 above, care being taken to remove as much free water in the sample as possible without withdrawing water from the plankters. Weight of empty dish subtracted from weight of dish containing evaporated sample will yield the amount of nondesiccated plankton (and possibly other associated materials) and results can be expressed in terms of any convenient unit of weight per liter

VOLUMETRIC METHOD

By obvious modifications of the gravimetric method just described, samples, wet or desiccated, may be measured volumetrically and results expressed in terms of volume per liter Ordinarily, however, the gravimetric method will be preferred because of convenience

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BOTTOM-FAUNA METHODS

Methods suitable for the study of bottom faunas must differ in order to meet the requirements of various kinds of bottom as they exist in lakes and streams.

Methods for Profundal Bottoms

QUALITATIVE METHODS

Since bottom deposits in profundal regions of lakes are usually of the soft, finely divided type, any bottom sampler such as an Ekman dredge, core samplers, or ooze suckers, which will collect these materials and transport them in unmodified form to the surface, may be used for qualitative work The construction and use of these samplers have been described on pp 175–186. The location and number of samples taken must depend upon the judgment of the operator, but clearly there should be a sufficient spread of an adequate number of samples over the area under consideration to insure that the survey is sufficiently complete for the purpose of the work

The treatment and analysis of samples taken for qualitative work by the Ekman dredge are very similar to those of samples for quantitative work, and since the latter must be described, the reader is referred to p 300

Material collected with the ooze sucker (Fig 53) is particularly favorable for qualitative analysis of microscopic organisms in the uppermost layers of bottom deposits Detection and isolation of microscopic animals in bottom mud are usually very difficult and examinations of living materials are much easier than those of preserved samples. Such samples should be examined first under a low-power binocular microscope. If necessary the sample should be diluted with filtered or tap water to reduce the concentration of the material As organisms are found they may be removed by means of a capillary pipet, transferred to a microscope slide, and examined under a compound microscope The ooze sucker is not suitable for quantitative work since it disturbs the finely divided ooze as it settles on the bottom, it collects a sample only from the uppermost layer of bottom deposits, and its efficiency is probably different on different kinds of bottoms Collections of profundal mud stored in a refrigerator will usually remain in good condition for several days Sometimes isolation of the organisms can be facilitated by dividing the sample

into fractional portions and putting them through one or more fine-mesh sieves.

QUANTITATIVE METHODS

Ekman Dredge Method

SUITABILITY Suitable for macroscopic bottom fauna, also for soft, finely divided bottom materials only

EQUIPMENT Ekman dredge, strong line for operating dredge, several large-size tubs or similar containers, 2 or 3 ordinary pails, several quart-size, wide-mouth jars with tops and with serial identification numbers, in field kit, several large, strong, circular screens with No 30 mesh (p. 186), forms for sampling records If large-size Ekman dredge is used, a suitable hoist is necessary.

Procedure

1 Inspect dredge for good working condition, thread messenger on line; attach line securely to dredge and tie opposite end of line to boat or hoist

2. Select first sampling position and locate boat above it, set dredge in open form, lower dredge into water so that it will descend vertically; on arrival at bottom, allow dredge to settle, release messenger, holding line with just enough tension to keep it straight. When dredge has closed, lift to surface with moderate, steady speed

3. On arrival at surface, lift dredge promptly from water, swing over large tub and discharge contents by pulling up each jaw chain two or three times, first on one side, then on the other, to empty dredge completely Again set dredge in open position, shift position of boat, lower into water and proceed with sampling as before Keep accurate record of number of samples taken

4. Spread sampling over selected area according to prearranged plan (scattered at random, or distributed along transects) and accumulate dredged materials until number of samples and quantity of bottom materials meet requirements of work.

5. When sampling is concluded, or when available tubs are filled, transfer dredged materials to shore for screening.

6 Select convenient place at shore in shallow, calm water, deliver small quantities (about 1–2 qt at a time) into screen, lower loaded screen into water to depth equal to about one-half height of sides, rotate horizontally, alternately clockwise and counterclockwise, and with sufficient vigor to wash finely divided contents through screen, making each swing through about 180°, facilitate screening by occasionally varying motions, such as short, rapid, vertical dips or sharp rocking motions, avoid loss of bottom material over upper edge of screen

7. After all finer materials have passed through screen, concentrate residue (screenings) at one edge of screen by judicious scooping motion of bottom of screen against surface of outside water, by means of spoon or similar article, carefully transfer screenings to wide-mouth sample bottle, refill screen and continue screening activities until all dredgings are used, careful cleaning of sieve is not necessary until end of screening of sample involved since residues left in sieve during process are not lost

8 Do not crowd screenings in bottles, include plenty of water in bottles, otherwise certain organisms will die, record serial numbers of bottles, close bottles securely, place in bucket of cool water, and protect against sun

9 If screenings are analyzed at once, no further directions are necessary If analyses must be delayed a few hours, store screenings in refrigerator, if delayed for longer time, preservation is necessary

Limitations

a This method is limited to bottom materials which are soft and finely divided Hard bottoms are excluded Intermixtures of sand interfere with mechanical operation of the dredge

b Because of the use of screens, only macroscopic bottom fauna is secured, the size of which depends upon the dimensions of the mesh.

General Considerations

a Samples may be scattered irregularly and at random over the area concerned, or samples may be made at intervals along transects which cross the area In either instance, the sampling is random since there can be no actual selection by the operator Transects have an additional value only when a knowledge of exactly where the samples were taken is important

b The number of sampler loads collected must be a matter of judgment by the operator, based upon the size of the area concerned, its degree of uniformity, the density of the population, and perhaps other circumstances A sufficient number must be taken to insure that the samples are truly representative

c When the open Ekman dredge is lowered too rapidly it may tend to "sail" off at some angle from the vertical The dredge must be lowered as nearly vertically as possible, otherwise it may not meet the bottom in the correct position

d If on reaching the surface the dredge shows leakage through the jaws, the difficulty will usually be caused either by grit between the side pieces of the jaws and the wall of the dredge body, or by hard objects caught between the edges of the two opposing jaws. Such a sample must be discarded.

e Some workers cover the top opening of an Ekman dredge, just under the top lids, with a fine-mesh brass screen to protect against loss of organisms by overspill when the dredge settles into the bottom Much depends upon the size of mesh of this screen since too coarse a mesh would accomplish little or nothing and too fine a mesh may interfere with the proper passage of water and bottom materials into the dredge. Ekman dredges made in tall form are sometimes used

f Field work is facilitated when boats providing high degree of stability are used, particularly on larger bodies of water.

g Change in position of the boat is imperative if the sampling is to be adequate. Such changes can be made in various ways, such as use of a very long anchor rope, portions of which are pulled inboard from time to time, periodic use of motor, and allowing boat to drift unanchored across the area to be sampled If transect positions are to be accurately known, the boat must describe definite courses from one set of shore signals to another, or operate under some other kind of guidance.

h In transporting dredgings to shore, cover tubs with a piece of wet canvas to protect against hot sun and against loss by sloshing caused by motions of the boat.

i. Screening of dredgings may be done on board boats at the time of sampling, but it is usually a laborious and sometimes a less accurate process, especially during times of rough water

j. The labor of screening may be reduced by the selection of convenient place and certain facilities at shore, as for example, a small dock, protected water, and a firm bottom. However, it must be remembered that large quantities of profundal muds screened into shallow water at shore may produce objectionable effects locally.

k On occasion it may be more desirable or convenient to wash dredgings on land at some outdoor hydrant. Tap water may be directed gently from a hose into the screens and screening accomplished satisfactorily in this manner.

l. Some workers have used strong bags with large windows of coarse grit cloth as a substitute for brass screens. Dredgings are placed in such a bag, the top closed, and the bag manipulated in the water or trailed behind a boat until the fine materials are removed. For most purposes it appears that screens are preferable

m If screenings must remain in storage for an indefinite time after collection, they should be preserved in a sufficient quantity of 10 per cent formalin to insure safekeeping. However, it should be remembered that preserved materials are more difficult to analyze.

n. At the end of sampling activities, wash all equipment, ropes, and boats before adhering bottom muds become dry. Wash screens with particular care.

Analysis of Ekman-dredge Samples

EQUIPMENT Large white porcelain pans, or 8-in. shallow culture dishes with white backgrounds, finger bowls, watch glasses, and similar glassware, pipets and medicine droppers with large apertures, sorting needles with recurved points, absorbent paper, burets or tall graduates, balances of suitable sensitivity.

Procedure

1 Transfer small portion of screenings to wide, shallow porcelain dish or 8-in. glass culture dish with a white background, add tap or distilled water until conveniently diluted, systematically examine all material, removing macroscopic animals by hand picking and sorting them in smaller dishes into various taxonomic groups

2. When all animals have apparently been removed, pour residue into special container, take another portion of screenings and continue examination until all screenings have been worked over.

3. Reexamine in similar way all residues and repeat at least twice Each succeeding examination of residues will probably yield animals although, if previous work has been well done, in rapidly declining numbers.

4. Sort, classify, and identify animals taken in sample, carry identification to that taxonomic step (family, genus, species) required by purposes of work, then employ one or more of following methods for calculating standing crop of organisms, depending upon use to be made of results

a *Survey Count.* Count all individuals in each of various sorting dishes, count only living animals, or if preserved screenings must be used, count only animals which were alive when sample was taken; record totals for each species, genus, or family, in proper space in some record form, compute for each individual group (differential count), or for grand total, the number of macroscopic animals in *1 square meter* by use of formula·

$$n = \frac{o}{as} 10{,}000$$

in which n = number of macroscopic animals in 1 sq m. of profundal bottom

o = number of animals actually counted

a = transverse area of Ekman dredge in sq. cm

s = number of samples taken at one sampling station

If total number of animals in whole profundal area is desired, multiply n in formula given above by total number of square meters in whole profundal area secured by measuring area within bounding submerged contour on hydrographic map, note that results will be in terms of number of profundal macroscopic animals which would occur if bottom within bounding contour were a plane.

b *Volumetric Method Procedure 1.* Transfer animals to absorbent paper and allow visible water to drain from them for about 1 min , if sample contains considerable numbers of organisms, move them gently about over paper, without scattering them individually, if mollusks and case-bearing caddis fly larvae are present, either the shells must be removed or some factor representing shell volume (or shell weight if gravimetric method is used) must be worked out and applied as a correction to the results. *Procedure 2* Place animals in graduated centrifuge tube previously calibrated against a buret having same graduation values, fix centrifuge tube in support which will hold it at about 45° angle, mouth downward, allowing liquid to drain off for about 3 min If drainage is done while animals are alive and active, insert wire-gauze plug in mouth of tube to prevent their escape, removing gauze plug at end of drainage period. Pour water into buret and read quantity, place centrifuge tube containing animals under buret outlet and admit water from latter until mass of animals is just covered, subtract amount of water admitted from buret from reading on centrifuge tube and result is volume of contained animals.

Compute for each individual group, or for grand total of all animals, *volume* of animals per square meter of profundal bottom by use of formula

$$V = \frac{v}{as} 10{,}000$$

in which V = volume of macroscopic animals under 1 sq m of bottom surface
v = volume of animals actually measured expressed in cc
a = transverse area of Ekman dredge expressed in sq cm
s = number of samples taken at one sampling station

If total volume of animals in whole profundal area is desired, multiply V in formula by total number of square meters in whole profundal area Same limitation holds here as described in preceding method

c *Gravimetric Method.* Follow procedure outlined under volumetric method, except that animals are weighed on balance of appropriate sensitivity and results expressed in terms of *wet weight*

General Considerations

a Instruments appropriate for isolation and sorting of bottom organisms are a necessity. Forceps, if used at all, must be employed sparingly and cautiously when soft-bodied animals are concerned since they are apt to cause fragmentation A dissecting needle bent at the point into a recurved hook is especially useful in handling annelids and insect larvae, also both ordinary insect pins (size No. 4 or 5) and insect "minuten" pins

mounted in small wooden handles and with points bent into sharply recurved hooks are recommended Medicine droppers and pipets of various types are also needed

b Those animals, such as Tubificidae, which fragment easily, present difficulties in counting Counting all fragments and dividing the sum by 2 is probably as good a solution to the problem as can be expected, although at best only an approximation.

c. In isolating and sorting live animals from the screenings, certain ones, notably Tubificidae, may tend to aggregate into compact masses. Usually such masses may be dispersed by judiciously thrusting a needle through the mass, transferring it to clean water in a large culture dish and then washing the mass vigorously back and forth through the water

d If for any reason two sets of screenings have been obtained, as for example, one from a No 30 screen and one secured by allowing the material passing through the No 30 screen also to pass through another screen of finer mesh such as a No 100, the material from the finer screen may be treated as follows Because of smaller size the organisms cannot be hand picked and sorted as in the coarser screenings, therefore, they must be examined and counted under a binocular microscope Furthermore, it will probably be impracticable to count the entire screenings, in that instance, an aliquot sample of the screenings (0 1 of screenings may be satisfactory) is selected and placed, wholly or in successive portions, in a shallow glass vessel of convenient size on the bottom of which fine parallel guide lines have been ruled, or to the lower side of which a piece of translucent, ruled and paraffined paper has been attached. Guide lines may be so disposed that the intervening spaces have a width slightly less than the diameter of the field of view of the microscope, thus making it possible to examine the entire field by moving its various subdivisions successively, from end to end, under the microscope Calculations of number of organisms in entire screening are made by computing from the number found in the aliquot sample the total number in the entire sample

e. Certain animals common to profundal muds are very transparent and may be overlooked unless a suitable background for the examination dish is provided and unless the observer is on the alert.

f. It seems to have been demonstrated that benthic organisms in general undergo shrinkage in volume after several months of storage in preservative and that the amount of such shrinkage is greater in alcohol than in formalin It therefore appears that for precise work, a correction factor must be worked out if and when specimens which have been stored for some time in preservative are compared with fresh material

g In *Procedure 2*, the excess liquid drains off but specimens do not lose moisture subsequently by evaporation, an important advantage when material preserved in alcohol is handled By this procedure it is possible

to eliminate much of the variation inherent in other methods used to reduce moisture to a near constant.

h. The volumetric method, particularly as outlined in *Procedure 2*, is distinctly advantageous for field use It does not require special, expensive, or delicate apparatus, and is relatively rapid in operation

Core Sampler Method

SUITABILITY Particularly suitable for quantitative study of microscopic organisms at various depth levels in soft and medium hard bottoms.

EQUIPMENT Vertical core sampler (p 182), several serially numbered glass tubes to fit interior of sampler, field case for glass tubes, operating line for sampler, corks for ends of glass tubes, collar weight for sampler to insure penetration in harder bottoms

Procedure

1 Examine sampler for good working condition; unscrew steel nose and insert glass tube, replace steel nose, attach operating line to sampler and tie other end of line to boat

2 Select first sampling position and locate boat above it, lower sampler rapidly and vertically into water, allow sampler to penetrate into bottom in vertical position with full force of its weight.

3 Haul sampler to surface and keep in vertical position; insert cork in bottom of sampler, unscrew steel nose and remove glass tube containing core of bottom deposit, insert cork in each end of tube, record number of tube, and store in field case *in vertical position*

4 Insert another glass tube in sampler and repeat procedure until sampling program is completed, transfer collected cores to laboratory. Store cores in refrigerator until ready for analyses. Never allow cores to be put into any position other than vertical

Analyses of Cores

Analyses of cores depend, in their details, upon the kind of data desired. The following procedure is designed to effect a complete general analysis in which information on both horizontal and vertical distribution is obtainable Modifications of this procedure may be made in order to adapt the procedure to special or limited purposes

EQUIPMENT Piston for removing cores from glass tubes (Fig. 56), rubber cup for top of tubes, rubber base for tubes, bulb syringe, 100-mesh screen, counting cell

Procedure

1 Remove stoppers at upper and lower ends of glass tube, insert properly fitted piston, made from part of rubber stopper, into lower end

of glass tube; install rubber cup (p 184) on upper end of tube, siphon off any clear water above core of bottom material in tube By means of graduated piston rod, push up piston some selected distance, displacing uppermost portion of core and spilling it into rubber cup, scrape off materials at top of tube even with margins, remove materials in cup with small bulb syringe, wash cup with tap water and recover any residual materials. Remove next lower portion of core in same fashion, and continue until all desired segments of core are successively removed

2 If necessary, take more than one core at same station, treat all cores from same sampling station in same way, mix together into one composite sample all materials representing same stratum in each core, if sampler sinks to different levels because of inequalities of bottom, make certain that *sections* from different cores are from corresponding levels, mix composite sample gently but thoroughly, remove aliquot part of composite sample for direct examination, transfer to counting cell for examination under microscope.

3. Transfer remaining portion of composite sample to 100-mesh screen, wash by passing tap water through sample, transfer screenings to counting cell for identification and count of larger animals held by screen.

4. Repeat procedures just outlined for all other strata of cores

5. Determine quantity of population by survey count method (p 303) and express results in number of individual organisms per selected unit area of surface of bottom, e g , number of organisms per square decimeter of bottom area.

General Considerations

a Choice of depth (thickness) of sections of cores must be made on bases of aim and desired precision of work.

b Since it is unlikely that the distribution of microscopic animals in bottom muds is uniform and since the transverse area of the sampler is small, a single core will have little more than exploratory value. For dependable results several cores must be taken at each sampling station

c Counting cells convenient for this kind of work are made in various ways A handy one is constructed by placing strips of adhesive tape on frosted-glass lantern-slide plates and coating the tape with paraffin The dimensions of the spaces between strips may be of any convenient value. Several parallel chambers on the same plate may be so made The chambers are placed on the frosted side of the glass. Frosted glass results in more evenly distributed illumination Chambers having the width of the microscope field of view are convenient.

d The amount of the composite sample counted directly will be determined by the degree of precision desired, also by the time required since at best this type of counting is very slow.

e. Theoretically, the use of the areal standard unit and the cubic standard unit (pp 290–295) is desirable, but practical difficulties arising from the fact that the mud is constantly an obscuring material makes the methods very difficult to apply

f. The extreme difficulty of removing all microscopic organisms from the mud practically precludes the use of any gravimetric methods for measuring these populations

Methods for Sublittoral Bottoms

Methods outlined previously for use of the Ekman dredge and the core sampler on profundal bottoms apply, with the same limitations, to soft and medium hard bottoms of sublittoral areas For harder bottoms, the Petersen dredge is required.

PETERSEN DREDGE METHOD

Suitability. Suitable for qualitative and quantitative work on macroscopic animals in and on hard bottoms; not practicable for quantitative work on microscopic fauna

Equipment Petersen dredge of convenient size, and weight, additional weights for dredge, hoist and wire cable for operating dredge, several large tubs or similar containers, 2 or 3 pails, several quart-size, wide-mouth jars with tops and with serial identification numbers, in field case, several large, circular, 30-mesh screens, forms for records

Procedure

1 Inspect dredge for good working order, attach securely to wire cable on hoist, install hoist in convenient operating position

2 Select sampling position and anchor boat over it, set dredge in open position, lower slowly to bottom, allow moment for dredge to sink into bottom materials, allow cable to go slack to release locking bar, raise dredge slowly to surface, swing inboard, and discharge load into tub

3 Proceed with sampling in way similar to that described (p 300) for use of Ekman dredge Send accumulated samples to shore and screen as described on p 300

4 For analysis of samples and computation of results, proceed according to outline given on pp 303–306

Operation of a Petersen dredge may be interfered with from time to time by objects caught between the jaws, preventing closure. Such imperfect samples should be discarded

At the beginning of a sampling program, one or more trial samples should be taken to determine whether additional weight should be attached to the dredge in order to make certain that it bites deep enough into a hard bottom.

SAMPLING ALONG TRANSECTS

The use of transects in sampling the sublittoral zone is of particular value because a sloping bottom is involved and because of the possibility that *concentration zones* occur in these areas. Unless sampling is done systematically and at relatively close intervals along transects which extend completely across the sublittoral zone, concentration zones may be missed entirely or be only partly sampled. It is unlikely that one transect will be adequate, several should be used and at such distances apart as to insure that the regions involved are properly sampled. During periods of calm water such transects present no serious obstacles, during rough water, they are very difficult or even impossible unless the work is done from a large boat. Various ways of keeping the boat at the proper intervals along a transect may be devised by the operator. In the smaller waters, the boat can be operated along a rope stretched from a heavy anchor sunk in deep water to some fixed object on shore. Or a set of shore signals may be so arranged that the courses of the boat and the sampling intervals are properly executed.

TOW NETS AND DREDGES

SUITABILITY. Suitable only for qualitative work with macroscopic bottom organisms.

EQUIPMENT. Tow dredges are made in a great variety of forms. The two described here are simple in construction, easy to handle, and ordinarily effective in performance.

TOW NET ON RUNNERS. This tow net, originally designed by Reighard, is very useful for collecting organisms just above soft bottoms. To an iron ring constituting the mouth of the dredge (Fig. 81) are attached four strips of band iron which extend radially for about 3 in., then make a rounded right-angle bend and extend parallel to each other for a distance of two or three feet where they make a round right-angle bend toward each other, meeting at the center. There they are riveted together. The dredge net, composed of strong materials and of whatever size of mesh is desired, is attached to the iron ring and extends backward within the framework of the iron strips. From the ring also extend three or four cords which are brought together to form an attachment for the towline.

Such a dredge sinks to the bottom and comes to rest horizontally, the four runners insuring that it will always assume an operating position. When hauled along the bottom by means of the towline, the runners act as a sort of sled, holding the mouth of the net about at the surface of, or slightly above, the soft bottom materials. In the sublittoral region such a dredge must be drawn either up the slope or parallel to it. When hoisted

to the boat the catch is deposited in appropriate containers by turning the net inside out

TRIANGLE BOTTOM DREDGE An equilateral triangle, with sides 12–15 in long, constructed from a piece of heavy band iron (Fig 82) about 3 in

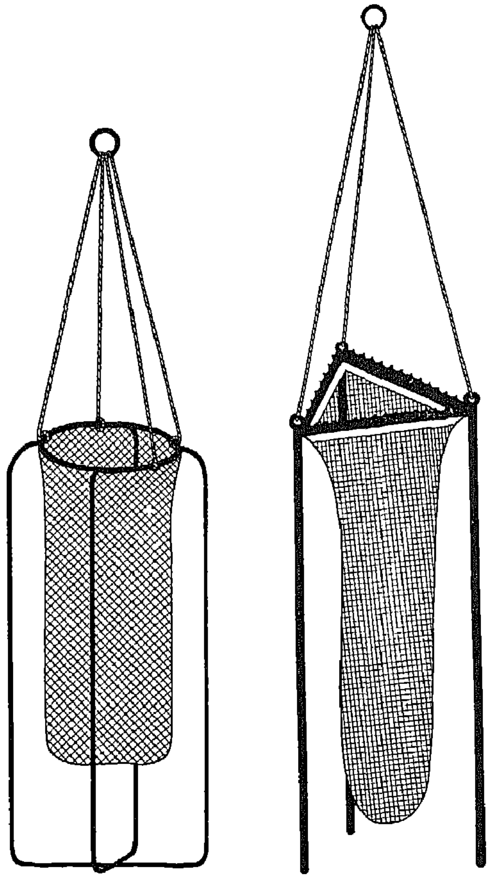


FIG 81. (*Left*) Tow net on runners, designed by Reighard for use on littoral and sublittoral bottoms.

FIG. 82 (*Right*) Triangle bottom dredge

broad, constitutes the mouth of the dredge One edge of each of the sides of the triangle is cut into a continuous set of large saw teeth. These teeth are bent outward so that when the dredge is hauled on the bottom they tend to dig into it. A loop at each corner serves as attachment for the towline At each corner there is fastened a stout iron rod, about 3 ft. long, which extends backward and ends freely To the smooth edge of the iron

triangle is attached the net which consists of (1) an outer supporting and protecting cover of burlap, coarse-mesh netting, or some other coarse, strong material, and (2) an inner lining of muslin at the bottom.

When attached to the towrope and lowered to the bottom, the rods insure that the dredge will always come to rest in the proper operating position. Drawn along the bottom, the toothed edge digs shallowly into the deposits and the catch thus contains those animals which are more or less imbedded in the uppermost layers of the latter. When hoisted to the top, the catch is delivered into containers by turning the net inside out. In the sublittoral region the dredge should be drawn either parallel to the slope or up the slope. Usually, it cannot be operated down the slope with any success without the use of complicated accessory arrangements.

Methods for Littoral Areas

Since, in general, the littoral zone shows the greatest diversity in bottom conditions of all lake regions, sampling methods must of necessity be chosen according to the kind of area examined. Qualitative work presents no special problems since any means of securing bottom samples will probably serve the purposes, but the requirements for quantitative work are more exacting. The first problem is the proper choice of a bottom sampler.

SAMPLING EQUIPMENT

Unit-area Sampler. A simple but effective unit-area sampler is made from a strip of spring sheet brass, $\frac{1}{16}$ in. thick, about 6 ft. long, 3–4 in. wide, with rounded ends. The length of the brass strip is such that it can easily be made into a circle which contains an area of exactly $\frac{1}{5}$ sq. m. At one end is a short bolt supplied with a wing nut, in the opposite end is a longitudinal slit the width of which is slightly greater than the diameter of the short bolt at other end. This slit fits over the bolt and the wing nut is tightened down to hold the two ends together. A circle of fixed area is thus produced, loosening the nut permits easy storage of the flat strip. At each interval of about 1.5 ft. along the brass strip there is riveted at the middle line a slender brass tooth, about 6 in. long, $\frac{1}{8}$ in. thick and $\frac{1}{2}$ in. wide, tapered gradually to a point at the free end. These teeth are fastened loosely on the rivets so that when not in use they can be turned parallel to the strip, simplifying storage. When ready for use the teeth are turned at right angles to the brass strip, the sampler is lowered into the water and the teeth are pushed into the bottom until the lower edge of the brass strip is buried a short distance in the deposit. One unit-area of bottom is thus definitely included. Such a device is best suited for barren sandy exposed shoals, although it may have a limited use on certain other littoral areas where conditions permit.

This unit-area sampler can be used only during periods of calm water When it has been sunk into the bottom at any location, the operator, using a strong pint dipper of the usual type, removes carefully the bottom materials included within the unit area to a depth of about 1–1 5 in Such materials are transferred immediately to a sieve of the appropriate mesh and screened Often this screening can be done by a helper standing only a short distance away Screenings are removed from the sieve and stored in the usual way (p 301) until analyzed.

PETERSEN DREDGE The Petersen dredge, described on p 178, is particularly suited to those littoral regions having hard bottoms, but with proper care and an understanding of limitations, it may be used on certain other areas

CORE SAMPLER The core sampler may be used on the following littoral regions barren sandy exposed shoal, protected sandy shoal, marly shoal, mud bottoms It is not recommended for rock, stony or gravel bottoms which prevent its proper penetration, or for bottom materials containing so much water that the cores will not be retained

SQUARE-FOOT SAMPLER A bottom sampler (Figs 83 and 84) described by Wilding (1940) consists essentially of two brass cylinders, one inside the other The outer cylinder, 30 in long, is open at both ends On the lower margin are fastened 13 large saw teeth by means of which the cylinder, when rotated, cuts its way into the bottom The diameter of the outer cylinder is such that exactly 1 sq ft of area is enclosed The inner cylinder fits closely within the outer one and is perforated with minute holes, each $\frac{1}{64}$ in in diameter and so spaced that there are 23 holes per linear inch or 529 holes per square inch At the bottom of the inner cylinder is a valve composed of two sets of overlapping horizontal blades so constructed that the inner cylinder can be closed or opened at the bottom The lower part of the valve is stationary, the upper part rotates on a shaft, the two parts forming a watertight bottom when in closed position. The valve is opened and closed by means of a special handle When the valve is open the blades are directly superimposed, when closed, upper set closes the openings in the lower one

When ready to use, the outer cylinder alone is rotated, toothed edge downward, to sink it into the bottom for a short distance All coarse materials (rocks, vegetation, debris) are taken out by hand picking, placed in a container partly filled with water and washed, the more obvious bottom organisms are collected and sorted by direct examination The water in which they were washed is poured through a piece of muslin loosely supported by a frame in order to secure the macroscopic animals which remain in the water After the gross materials on the surface of the bottom area within the outer cylinder have been removed to a depth of 3–4 in., the remaining bottom materials are stirred thoroughly The inner cylinder,

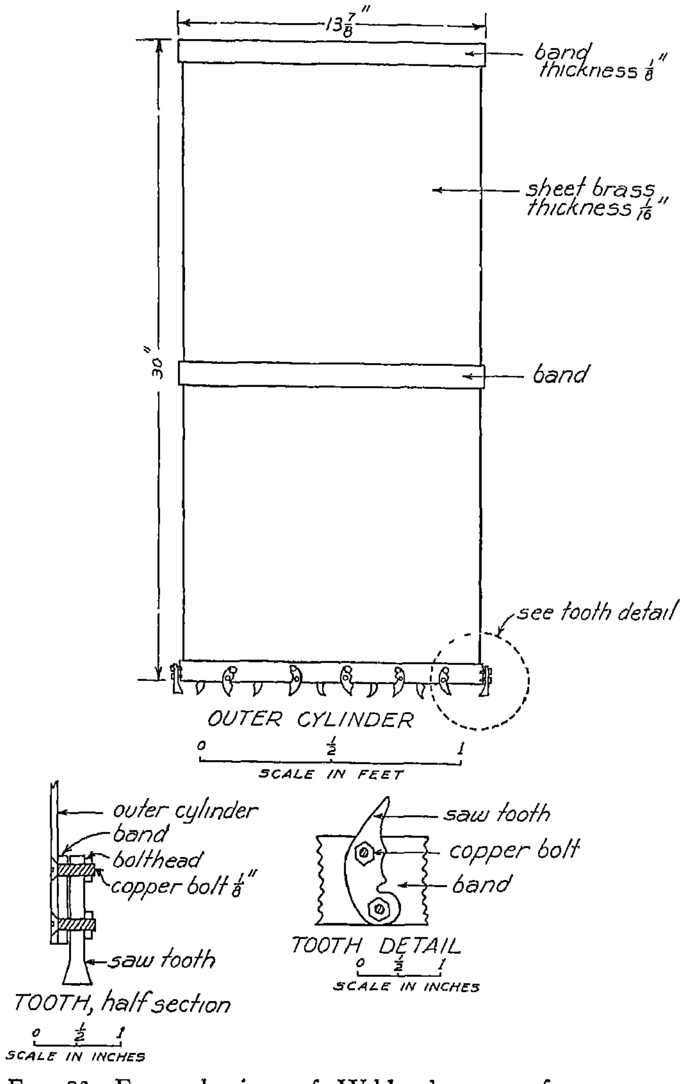


FIG 83 External view of Wilding's square-foot aquatic sampler (From Wilding, 1940)

with the valve set in open position, is then inserted into the outer cylinder and plunged to the bottom, forcing the water contained in the outer cylinder through the openings of the valve When the inner cylinder is pushed as far as it will go, the valve is closed by turning the handle which controls it Then the inner cylinder is lifted out and the contained water allowed to strain out through the perforations, leaving the organisms thus collected inside the cylinder This catch is washed out into a large re-

ceptacle and the water containing the organisms is then poured through the muslin cloth previously mentioned to complete the capture.

This sampler provides positive capture of practically all bottom organisms within the area selected, with the exception of those minute ones which pass through the perforations in the inner cylinder It can be used

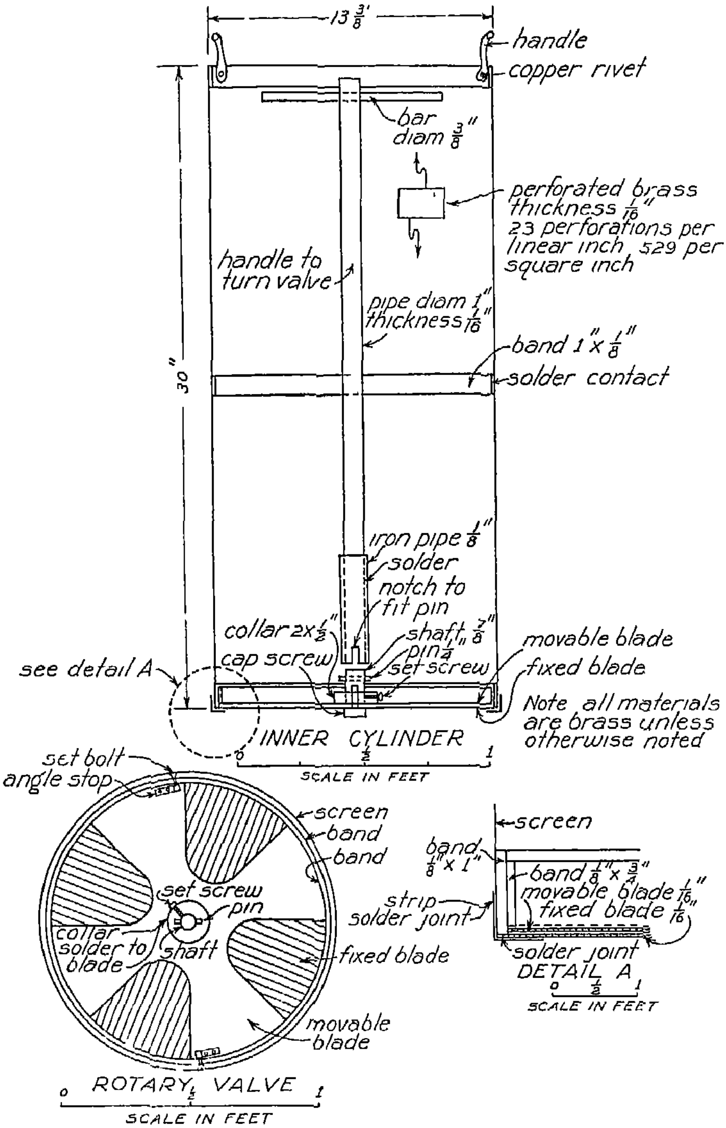


Fig. 84 View of internal construction of Wilding's square-foot aquatic sampler (From Wilding, 1940)

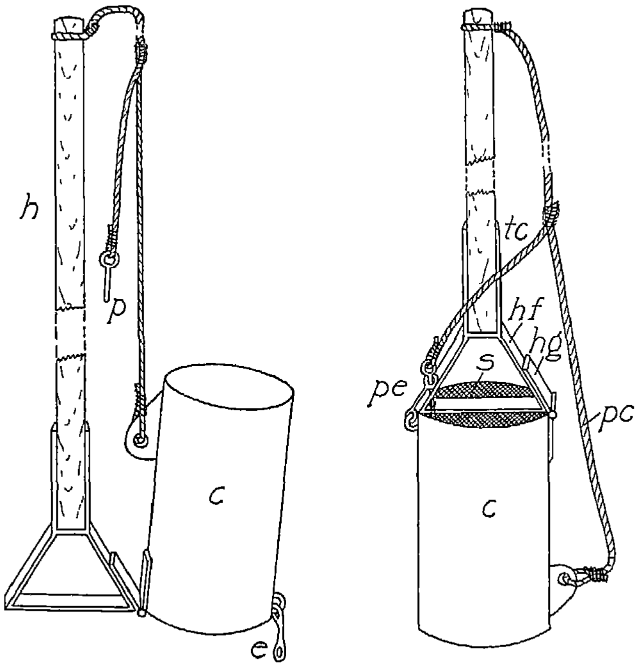


FIG 85 Dendy inverting sampler (*Left*) Sampler inverted. (*Right*) Sampler in operating position (*c*) Cylinder (*e*) Eye. (*h*) Handle (*hf*) Handle frame (*hg*) Hinge. (*p*) Pin (*pc*) Pull cord (*pe*) Pin-and-eye lock (*s*) Screen. (*tc*) Trip cord (From Dendy, 1944)

in various kinds of littoral regions of lakes, in weed beds, and in gravel and rubble areas of streams All parts are made of brass or copper.

EKMAN DREDGE. The Ekman dredge described on p. 176 can be used only in the soft, finely divided littoral bottoms which are free from vegetation, intermixtures of sand and miscellaneous coarse debris.

DENDY INVERTING SAMPLER A very useful and convenient sampler of the inverting type (Fig 85) was devised by Dendy (1944) for work on littoral areas The main feature of the sampler consists of a brass cylinder 7.8 cm. in diameter and 13 cm long. The top end of this cylinder is covered with brass screen the size of mesh of which can be varied to suit the character of the work No. 30 mesh is a good average size A handle frame is fastened to the top of the cylinder by a hinge on one side and by a pin-and-eye lock on the other A wooden handle of suitable length is fitted into this frame. From the free end of the handle a pull cord extends to the bottom of the cylinder on the hinge side where it is tied into a projecting wing provided for that purpose A trip cord, extending from the pin to the pull cord, is so adjusted that when tension is exerted on the pull cord

the pin is withdrawn, releasing the lock, and then additional tension inverts the cylinder.

To secure a sample, the sampler is set in the position shown at the right in Fig. 85. By means of the handle the cylinder is pushed vertically into the stream or lake bottom to a depth about equal to its height. At the end of the downward push on the handle, the operator inverts the cylinder by further pull on the cord. This inversion of 180° insures that the full sample is secured and that on the trip to the surface of the water the only loss of material is that which may drain through the brass screen. When the sampler reaches the surface its contents are discharged into a screen and treated as described elsewhere (pp. 300–302), stored temporarily in an ice box, or preserved.

This sampler is suitable for use on bottoms composed primarily of mud, sand, marl, fine gravel, and similar materials into which the collecting cylinder can penetrate readily. Its capacity is small enough so that the entire sample may be analyzed without subdivision. This size also makes it possible to secure a larger number of samples spread more extensively over the area involved. It is easily handled by the operator while wading in shallow water and samples are taken rapidly. It may also be operated from a boat. Within limits, the handle and pull rope may be extended to a length which makes possible sampling in deeper water. The size of the mesh of the brass screen covering the upper end of the cylinder may be varied according to the needs of the work. This sampler will collect samples from bottom materials which contain an unusual component of water or which, because of some other feature, will not remain in the tube of a core sampler.

DISTRIBUTION OF LITTORAL SAMPLES

In some instances, the manner in which littoral bottom samples are spread over the whole area under consideration may be of little consequence, in others, special reasons may require a careful choice. The principal types of distribution are as follows:

Dispersed Random Sampling. By dispersed random sampling is meant the completely irregular selection of sampling positions. The essential requirements of such sampling are (a) samples should be scattered over the entire area involved, (b) conscious choice in the selection of any sampling position must be rigidly excluded, and (c) a sufficient number of samples must be taken to meet the precision requirements of the work.

Transect Sampling. Transect sampling has an important advantage over dispersed sampling, namely, that the position and distribution of samples are known and can be definitely mapped. In addition it may be easier to provide the distribution of samples over the area concerned and still maintain the requirements of random sampling. Transects may be

transverse, parallel, or diagonal, to shore line depending upon circumstances and the character of the work.

Transect sampling is of two general types: (a) line transects, and (b) zonal or belt transects.

By a *line transect* is meant either the regular or irregular scattering of samples along a predetermined line which extends across the area concerned. It results in a single row of sampling positions in which the essentials of the random sampling method are met. If a sufficient number of samples is taken, it may be of little consequence whether the samples are all the same distance apart, or whether there is no regularity of intervening distance just so long as no conscious choices are involved and so long as obviously abnormal groupings of samples are avoided. Any substantial program of bottom study will almost certainly require several transects the position of which must be determined by the special features of the area. The position of transects should be located by permanent objects on shore, by measurements and sets of marked stakes, or by data secured with surveying instruments. When properly referenced to permanent shore features, a set of line transects can be accurately drawn on maps.

By *zonal* or *belt transects* is meant those which have a definite *width* as well as length. Such transects may be used in many ways. For example, zonal transects may be laid out and samples confined to them although *within* them the samples may be of the dispersed random type. In some situations zonal transects are of particular value for measures of the standing crop of the larger, visible animals, such as clams and snails. Dependable surveys of the clam population may be made by two observers who hold between them a light pole of known length and traverse an area, back and forth, counting all individuals which occur in the space between the observers. From several such zonal transects distributed over the area as a whole, very satisfactory computations of the standing population may be made.

ANALYSES OF LITTORAL SAMPLES

The general procedure for analysis of screened samples of the profundal region (p. 300) is suitable for analyzing the screenings from the littoral zone. Unfortunately no means has yet been devised for all littoral materials which eliminates the tedium and time consumption inherent in the necessary hand-sorting methods. However, for formalin-preserved screenings in which there is a preponderance of sand or fine gravel and minimal amounts of flocculent materials, the calcium chloride *flotation method* is very useful. This technique consists essentially of the following steps: (a) drain off excess formalin from each sample, (b) divide sample into convenient portions, (c) place each portion in large evaporating dish, (d) cover portion with a saturated solution of calcium chloride and

stir vigorously. The high density of the calcium chloride solution causes all arthropods, excepting caddis fly larvae in sand-covered cases, to rise to the surface while the sand and gravel quickly settle to the bottom. The specimens are picked or skimmed off the surface of the liquid. Annelids and mollusks may be poured off after vigorous stirring and before settling can occur. The supernatant fluid should be poured through a piece of fine marquisette stretched over the mouth of a funnel to secure animals which are missed. The materials remaining behind in the evaporating dish should be stirred and washed 3–5 times in the manner just described and then placed in an 8-in. culture dish for further examination, first over a dark and then over a white background, with a large-diameter 10× reading glass for the capture of any organisms missed in the chloride treatment. The residue on the marquisette is washed into a finger bowl and examined under a binocular microscope. In some materials more than 95 per cent of the arthropods, caddis fly larvae and annelids may be so collected. Mollusks are effectively removed in this way only when very small. The calcium chloride can be used repeatedly but the full strength must be maintained otherwise loss of buoyancy results. The method as outlined here is a modification and simplification of one described by Beak (1938).

Increased speed in collecting and sorting littoral animals in screenings has been claimed for the sorting trough (Fig. 86) designed by Moon (1935) which partially grades and arranges the materials examined. It consists essentially of a trough, 1.3 m. long, with a bottom made of plate glass. This trough is divided into three compartments by two incomplete partitions *p* so arranged that the gap between the end of one partition and the side of the trough is on the side opposite that of the next one. Water is admitted into the upper end of the trough through a lead pipe *w*, 1.3 cm. in diameter, in which linear series of holes provides that the water enters the first compartment in the form of a diffuse jet. Entering water is controlled by a valve and leaves the trough at the lower end through a hole, 2.5 cm. in diameter, into which a short pipe is fitted. This pipe discharges into a small trough which in turn empties through a series of sieves *s* or filters and thence into the final drain. A strip of metal *st* 1.3 cm. high is installed across the front end of the pipe. The plate-glass bottom should be painted white on the outside surface, or the whole apparatus set over a white background. When in use, the original screenings are placed in the first compartment and water admitted by adjusting the tap. As water passes through the trough, a swirl is produced in front of each partition and before the lower end of the trough, thus producing a sorting effect. The heavier materials remain in the upper compartment while the lighter ones collect in the lower two compartments. The lighter debris and the smaller animals pass on through the pipe and smaller trough into the screens. Rate of current through the apparatus may be partly controlled

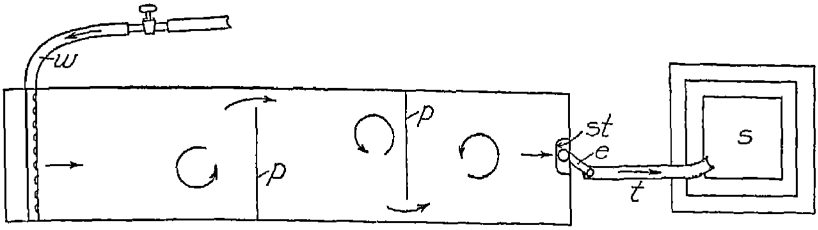


FIG 86 Diagram of Moon's sorting trough for littoral bottom materials Arrows indicate flow and performance of water. (*e*) Effluent pipe (*p*) Partial partitions (*s*) Sieves (*st*) Strip of metal about opening into effluent pipe (*t*) Drain trough (*w*) Water pipe (Redrawn with slight modifications from Moon, 1935)

by tilting the main trough After sufficient sorting effect by the water current has been effected, the water is turned off and the exit is closed by inserting a cork into the pipe The accumulations of materials in the compartments are then carefully raked apart and the animals removed by hand picking Material collected on the screens is washed into a white enamel sorting pan divided into numbered compartments These subdivisions focus the attention upon one compartment at a time thus making sorting easier and more accurate Since the partitions in the main trough are removable, the apparatus is adaptable to various modifications of the procedure If, for example, the sample is small, the partitions may be removed and the light materials washed directly through to the screens If the original screenings are too light for sorting, a small amount may be put through the trough, worked over, washed away, and replaced by the next portion.

METHODS FOR DIFFERENT TYPES OF LITTORAL BOTTOMS

1 SANDY AND FINE-GRAVEL SHOALS. For *qualitative* sampling, various kinds of scoops, dredges, drag nets, and other devices which collect surface layers of such a bottom are generally satisfactory In the less accessible or deeper situations some use may be made of the *tray method.* A collection tray consists essentially of a metal-rod frame of convenient size and shape to which is attached a very shallow bag of strong sacking or similar material The frame is provided with a bridle by means of which the tray is lowered and raised The tray is loaded with clean bottom materials of the kind present in the area to be sampled, then lowered to the bottom, allowed to remain there for some days or weeks, then raised and the contents analyzed for the bottom organisms which have colonized the materials in the tray Various accessories may be added to the tray to increase the ease and effectiveness of its use

For *quantitative* work, the Petersen dredge and the core sampler are

recommended. In the shallower portions of the area the unit-area form (p 311) has some advantages Trial samples must be run with Petersen dredge and the core sampler to determine the amount of weight necessary to cause these samplers to function properly

2 Stony and Coarse-gravel Shoals For *qualitative* sampling, heavy drag dredges or scoops, heavy hand-dip nets, rake dredges, and similar heavy-duty devices are necessary Some limited use may be made of the tray method (p 319) For *quantitative* work, some form of the unit-area method (p. 311) appears to be the most satisfactory In the deeper areas, quantitative sampling may be very difficult and sometimes uncertain The tray method may have some possible use in such areas but great care must be exercised that the tray samples are truly representative of both the kinds and quantities of bottom animals.

3. Rock Surfaces Rock surfaces are very difficult to sample adequately, especially for quantitative results *Qualitative* collections may be made by brushing the surface materials into the open end of a dredge or dip net For *quantitative* work, results for some purposes may be obtained, in shallows and under conditions of calm water, by marking off a known area and then, by direct observation, counting the organisms In deeper water some limited use may be made of the method of scrubbing a known area with a brush and sweeping the materials into the open mouth of a dredge provided with a flat lip Some workers have attempted to make use of the method of transferring rocks from the bottom into a submerged container, bringing them to the surface, and determining the quantity of fauna in terms of some selected unit of rock-surface area

4 Soft Mucky Bottoms Soft mucky bottoms present fewer sampling problems than any other littoral areas The Ekman dredge, Petersen dredge, and core samplers, usually provide adequate means of securing both qualitative and quantitative samples Many of the simpler dredges, nets, scoops, and similar devices are useful for making qualitative examinations.

5 Marl Bottoms Bottoms containing very large amounts of marl will probably require a Petersen dredge or a core sampler Only on the soft marl bottoms having considerable intermixture of organic matter and silt is there any chance that an Ekman dredge might be used for quantitative purposes

Methods for Stream Channels

Most of the methods already described as suitable for lake bottom are adaptable to stream-bottom conditions and need not be repeated However, certain methods particularly suitable to bottom conditions in streams have been developed, two of which (use of Surber's stream-bottom sampler and Hess' circular sampler) are described here

STREAM-BOTTOM SAMPLER

A stream-bottom sampler (Fig 87), originally described by Surber (1937), is now widely used It consists primarily of two square frames of equal size hinged together One frame carries the net and the other, when in working position, encloses the sampling area (1 sq ft). Two braces provide means of locking the two frames into working position at right angles to each other. The net is attached to the vertical frame by means of four brass strips screwed onto the sides of the vertical frame The net is composed of No. 000 XXX extra heavy silk bolting cloth and is 27 in in length. It may be attached directly to the frame, or if added durability is desirable, a section about 12 in. long composed of muslin or light canvas may be attached to the metal frame and the bolting cloth net of correspondingly reduced length sewed to the opposite end Two triangular wings, either of canvas, muslin, or bolting cloth fill the space between the vertical and horizontal frames on each side All metal parts should be made of brass to prevent rusting When not in use the whole sampler folds into a compact, flat form convenient for carrying in a field kit. A short handle installed in a vertical direction on top of the net-bearing frame may be convenient but is not a necessity

SUITABILITY. Especially suitable for sampling in stony or gravelly bottoms in regions of streams which are shallow and possess current enough to hold the net in an open position and wash the dislodged organisms into it For other types of stream bottom its use is limited and in some instances impracticable. Only macroscopic organisms are collected.

Procedure

1. Set net in open position and fasten wing braces securely in place, select sampling position in stream, approaching it from the side or from a downstream position

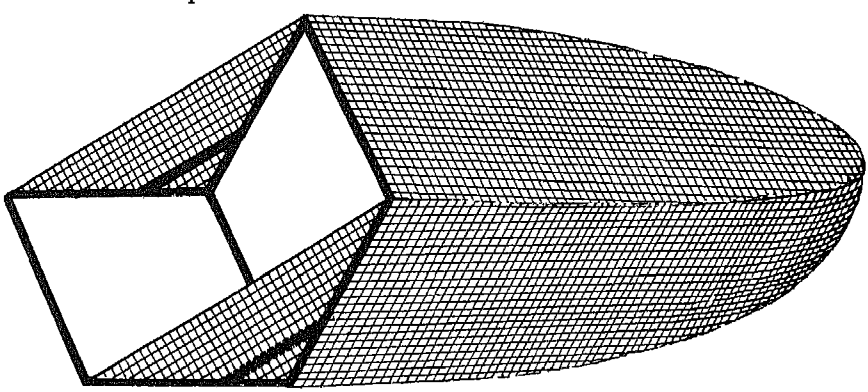


FIG 87 Surber's stream-bottom sampler

2 Grasp net by handle or, in absence of handle, by vertical frame, lower into water with open end upstream, work lower edge of horizontal frame into bottom until one-square foot area is completely enclosed, if spaces still occur under edge of horizontal frame, close them by pushing outside bottom materials against side, make sure that net is floating out in operating position

3. Turn over and stir stones, gravel and other coarser materials enclosed by horizontal frame, allowing dislodged materials to float into net, make certain that all materials within frame are stirred thoroughly to a depth of at least one inch

4 When mixing of materials within frame is completed, keeping open end upstream, lift net from water into vertical position and allow water to drain out of net Transfer organisms collected in net to appropriate receptacle by turning net inside out, receptacle should contain water if temporary live storage is planned

General Considerations

a If the triangular wings fail to present sufficient area, rectangular wings may be installed on folding metal arms

b The form of the net is not a matter of prime importance although a rounded terminal section may be convenient

c Size of mesh in the net may depart from that indicated (p 321), especially in direction of larger dimensions, if the purposes of the work warrant. Smaller meshes are subject to increasing inconvenience due to clogging

d. Since the net is subject to considerable pressure when in use, all seams must be broad and substantial

e In stirring materials enclosed within the horizontal frame, care must be taken to avoid undue bringing of fine sand into suspension since it will accumulate in the net and cause much difficulty in handling samples, also damage to net may result from overloading its contents.

f. Ordinarily it is not practicable to collect from more than one square-foot area before emptying the net

g This type of apparatus is impracticable for work in the quiet sections of streams since its performance depends upon current It is also impracticable for work in water deeper than arm's length

h. Some workers have partially overcome the difficulty of making the horizontal frame seat completely on rough bottoms by padding the frame with burlap or some other coarse cloth which is sufficiently compressible to pack into uneven spaces

i. At the conclusion of work, the net must be thoroughly rinsed out in clean water and then allowed to dry in open air but protected from direct sunlight

WILDING'S SAMPLER

Wilding's aquatic sampler, described on p 312, is suitable for use in gravel and rubble bottoms of shallow streams

HESS' CIRCULAR SAMPLER

Recently Hess (1941) has described another form of circular, square-foot sampler suitable for gravel and rubble bottoms of streams which overcomes some of the difficulties sometimes encountered in the use of Surber's square bottom sampler. The body of the sampler is in the form of a cylinder, about 18 in tall and somewhat streamlined in cross section The frame of this body is composed of a top and bottom hoop of ⅛ × ¾-in. strap iron, both horizontal in position These hoops are welded to two vertical, 0.5-in iron rods which are opposite each other Projecting ends of these rods are bent at the top into a horizontal position to form handles. The inside diameter of the bottom hoop is such as to enclose exactly 1 sq ft. of area A ⅙-in mesh galvanized wire netting covers the front half of the cylinder The back half is covered with heavy canvas in the rear of which is an opening, 1 ft square, over which the collecting net is sewed. The net, about 24 in long and conical in shape, is constructed of heavy grit cloth, No 24 (23 meshes to the inch) A finer mesh may be used if desired. The circular form of the lower hoop and the strong handles make it possible to turn the lower hoop into the bottom even in the presence of rocks of considerable size, the screen guard on the front surface prevents escape of larger organisms and keeps rocks from rolling into the sampler, and the streamlined form eliminates swirling.

The method of taking samples is essentially the same as that described for the stream-bottom sampler (p. 321)

Analyses of Stream-bottom Samples

Methods of analysis of samples taken from bottoms of stream channels need not differ from those already described (pp 299–308) for samples taken by the Ekman dredge, the ooze sucker, the Petersen dredge, and core sampler All of these instruments may be used effectively on stream bottoms just so long as the limitations of each are observed Samples taken with Surber's, Wilding's and Hess' samplers may be analyzed by the same methods described (pp 308–321) for those samples taken in different kinds of areas on the littoral and sublittoral zones Calculations are made, and results are expressed, in the ways already described (pp 303–305)

Methods for Psammolittoral Areas

It is now an established fact that sandy beaches, particularly that zone sometimes designated as the inner beach (that area extending from the

water's edge, during periods of calm, up the slope to the place where the surface of the sand ceases to be saturated with water and shows first traces of drying), maintain a population of organisms, often of considerable diversity and magnitude Special methods are required for these situations The following method was developed into its present form in the writer's laboratory by Neel (1948) Certain of its features are based upon earlier procedures devised by Pennak (1940)

EQUIPMENT. Several pieces of seamless brass tubing, 12 in long, 1 5 in. in diameter, with walls 0 02 in. thick, at least 2 brass tubes of same dimensions but 18 in long Piston, 2.5 in long, fitting snugly inside of brass tubes, and composed of 3 sections of good quality cork, each 0 6 in thick, separated from each other by a thin metal disk, all closely fastened together into compact plunger Piston is mounted on brass rod with diameter, 0.2 in , length, 1.5 ft Good grade No 8 rubber stoppers top diameter, 1.5 in , bottom diameter, 1 25 in , thickness, 1 in Field kit provided with supports which hold tubes in vertical position.

PROCEDURE FOR SAMPLING

1. At position of sampling, thrust open tube into sand to desired depth; remove carefully and insert rubber stopper in each end of tube without disturbing core of material, keep tube in original vertical position, transfer to field kit and continue to keep in vertical position.

2 Secure subsequent samples in accordance with predetermined sampling program which may be according to dispersed random method or in accordance with some plan of transect sampling, transfer to laboratory for analysis.

GENERAL CONSIDERATIONS

a Depth of sampling must be determined by the object of the work and by trial tests before the formal program is begun If a complete survey of the psammolittoral organisms is contemplated, sampling may require cores at least one foot or more in length since some organisms occupy depths much greater than was formerly supposed

b Transverse transects across the beach are likely to be the most useful plan of sampling

c It may not be practicable to sample by this method those beaches which are composed of light, finely divided muds with a large component of water, since cores may not remain unchanged in the tubes

ANALYSIS OF PSAMMOLITTORAL SAMPLES

1. Remove stoppers from sampling tube and insert piston into lower end, push core toward upper end and remove segment of core of required

thickness by cutting off with spatula or thin knife, place sample so secured in large flat dish

2 By proper methods of subdivision (or use whole segment of core if of small volume), remove 10 cc of segment of core, place in 3-in. diameter evaporating dish, and cover with about 50 cc of tap water

3 Introduce air jet of near capillary size into sand under water and adjust air pressure so that continuous stream of fine bubbles is produced, having force enough to bounce sand grains about but not enough to blow water over rim of dish Allow air jet to stir sand vigorously for 3 min., separating sand masses into individual grains and providing thorough washing.

4 At end of 3-min period of agitation, transfer water to two hand-centrifuge tubes and centrifuge.

5 After centrifuging, pour supernatant water back into 3-in evaporating dish containing sample, stir concentrate in bottom of centrifuge tube and transfer to concentrate bottle.

6 Repeat this process (paragraphs 3–5) three or more times for each sample, using the same water over and over. After last centrifuging, rinse tubes with tap water and add this wash water to concentrate

7 For identification and enumeration of concentrate, follow directions given for counting plankton (pp 285–295), also make computations in same way.

GENERAL CONSIDERATIONS

a. Since some of the psammolittoral biota are very small, thin counting cells permitting use of higher magnifications of microscope may be required

b Volumetric or gravimetric measurements are often impracticable because of the difficulty of separating the organisms from the residual fine sand.

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METHODS FOR PLANT-INHABITING ORGANISMS

Methods for Periphyton

Periphyton is that assemblage of organisms which commonly forms upon surfaces of submerged plants, wood, stones, and certain other objects, forming a more or less continuous slimy coat It may develop from a few tiny gelatinous masses into a woolly, felted coat that is slippery to the touch or crusty with included marl or sand.

Qualitative Methods Collection of periphyton for qualitative study requires no special equipment or approaches Material may be scraped

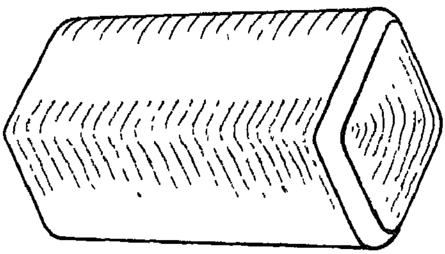


Fig. 88 Hollow-square instrument designed by Young for securing quantitative samples of periphyton from hard objects having large areas

from rocks, petioles of aquatic plants, or other supports and brought into the laboratory. There is every advantage in the use of fresh, living material since preservation produces changes in many of the organisms Usually, material should be collected under water, although some of the larger rooted plants, such as the bulrushes, can be cut off just above the bottom, allowed to rise to the surface, and pieces of the submerged portions introduced, with a minimum of disturbance, into bottles containing water.

Quantitative Methods Quantitative samples can be secured from aquatic vegetation by carefully cutting off sections of stems, petioles, and leaves, under water and introducing them into bottles also under water Sections of roots, dead brush and similar harder materials may be cut off with tin shears and introduced into bottles in the same way Quantitative samples of materials on stones, logs and similar surfaces can be secured by the use of a hollow-square instrument (Young, 1945) (Fig. 88) made by

bending a piece of sheet brass so that the inside dimension of each side of the square is 1 or 2 cm depending upon how large a sample is desired. One edge of the instrument is beveled and sharpened so that when it is set down upon a surface covered with periphyton it cuts through and encloses a measured area. The material in a zone outside the instrument is scraped away leaving the periphyton within the sampler as an isolated island. The sampler is removed and the enclosed sample is scraped off into a container.

ANALYSES OF PERIPHYTON SAMPLES

Numerical Methods

EQUIPMENT. Large counting cell (Fig. 89), made by cementing together pieces of plate glass to form cell 30 × 4 × 0.6 cm inside measure-

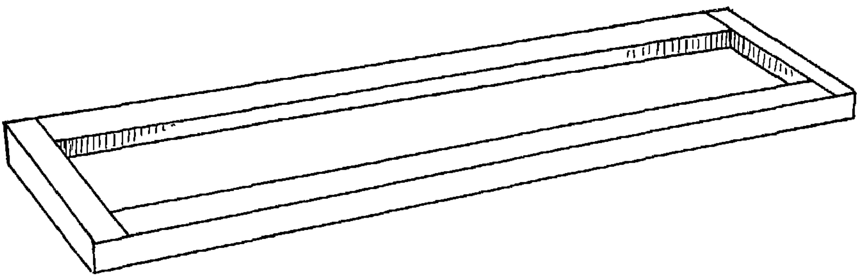


FIG. 89. Large glass counting cell designed by Young for examination and counting of larger periphyton organisms.

ments and having a capacity of 72 cc., binocular microscope, compound microscope, Sedgwick-Rafter counting cell, Whipple ocular micrometer, wide-mouth pipet.

Procedure

To count *larger* periphyton organisms, proceed as follows:

1. Deliver sample, or known portion of sample, into large counting cell.

2. Tease apart all compact fibrous masses.

3. Place cell under binocular microscope and make total count of all larger organisms in cell.

4. Compute and express number of each of different kinds of organisms per square decimeter of original surface and enter on record.

To count *smaller* organisms, such as diatoms, rotifers, and nematodes, proceed as follows:

1. Tease apart all masses in sample and mix thoroughly.

2. With wide-mouth pipet, remove amount sufficient to fill Sedgwick-Rafter counting cell, examine and count organisms under compound

microscope equipped with a Whipple ocular micrometer, counting all rotifers and nematodes in entire cell, and all diatoms, desmids, and organisms of smaller size in ten 1-cu mm. areas selected at random

3 Compute number of each of different kinds of organisms per square decimeter of surface from which sample was taken

Volumetric Method

EQUIPMENT Small stender dish, hard-surface filter paper, narrow graduate, or small graduated centrifuge tube

Procedure

1 Add convenient amount of water to sample, stir thoroughly and filter through small piece of filter paper, allowing all parts of filter paper used to become saturated with water, allow to drain completely

2 Place carefully measured, convenient volume of distilled water in stender dish, carefully transfer piece of filter paper bearing periphyton to water in stender dish and carefully wash off all periphyton, remove filter paper, allowing all excess water on it to drain back into dish

3. Transfer water containing periphyton to graduate or centrifuge tube and measure volume; volume of original water subtracted from volume after periphyton is added yields volume of periphyton.

4 Compute and express results as number of cc per square decimeter of original surface supporting periphyton

Gravimetric Method

EQUIPMENT Filter paper, balance of appropriate sensitivity, drying oven with heat control.

Procedure

1 Select filter paper, weigh carefully

2 Filter sample through filter paper, drain fully

3 Transfer filter paper and periphyton to drying oven and evaporate to dryness, temperature controlled at 60° C.

4 Weigh dried sample, subtract weight of filter paper from total weight, difference represents dry weight of periphyton

5. Calculate and express results in terms of grams per square decimeter of original periphyton area

General Considerations

a Volumetric and gravimetric measures of periphyton samples may sometimes be subject to sizable errors due to the presence of sand or marl. Separation of sand and marl from periphyton is difficult and sometimes impracticable

b. Periphyton samples may be concentrated by the use of a centrifuge.

c. Pieces of silk bolting cloth may be substituted for filter paper in volumetric measurements if *net* periphyton will suffice for the results desired

d. Certain plankton methods (pp 385–395) may be adapted for quantitative studies of periphyton

Methods for Vegetation-inhabiting Animals

WISCONSIN TRAP METHOD

Trap Construction

A frame (Fig. 90), approximately square, with inside dimensions of 36 × 37 cm, made from brass strip 2 5 cm wide and 3 mm thick, two halves of frame independent and attached to each other with double hinge so that when doubled upon each other the edges meet evenly, one row of closely spaced small holes parallels edges opposite closing ones, affording means of attachment for net, an elongated net 85 cm long with transverse dimensions approximately same as brass frame, sides made of light canvas or drilling and bottom of No. 72 extra heavy grit gauze.

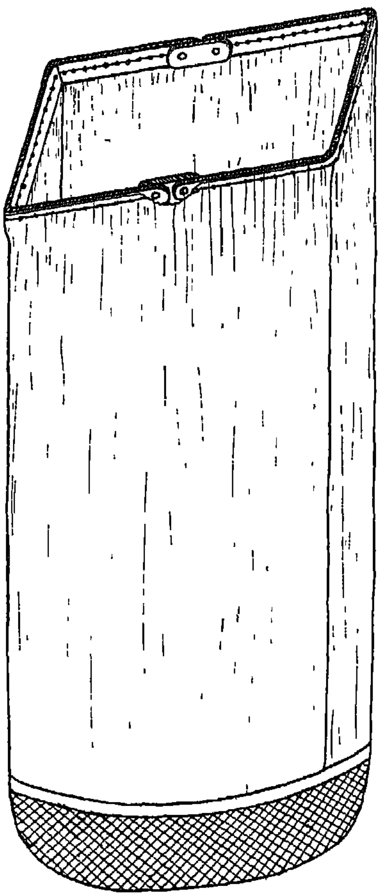


Fig 90 Trap for plant-inhabiting animals, Wisconsin design.

Suitability. Suitable only for work in shallow water, for macroscopic animals living on exterior of plants, and for work with submerged and floating aquatic plants.

Procedure

1. Hold trap in vertical position, jaws downward and wide open, lower carefully over plants to be examined, loosen plants from bottom and close jaws of trap, invert trap into position with jaws at top, bring to surface and pull entirely out of water, allow water to drain out through grit gauze at bottom of net

2 Transfer plants to large tub containing tap or filtered water, wash

plants in this water thoroughly to remove all animals, also turn net of trap inside out and rinse in same water to secure any animals dislodged in process of operation of trap.

3. Pour contents of tub through sheet of No 72 grit gauze to concentrate the catch.

4. Sort, identify and enumerate caught animals according to methods described on p 303 Express results in terms of number, weight, or volume of animals per square meter of bottom on which plants grew

General Considerations

a By use of a diving outfit this trap can be used to depths of 5–6 m

b. Ordinarily two individuals are required for operation of this trap, one in the water to make the catches, and one to haul in apparatus and remove collection.

c If desirable, the plants can be weighed (wet weight) after the water has been drained off, and the results of the enumeration of animals can be expressed in terms of number, weight or volume of animals per unit of weight of the plants concerned.

STREAM-BOTTOM SAMPLER METHOD

EQUIPMENT Surber's square stream-bottom sampler (p. 321), accessories

SUITABILITY Suitable for low-growing bottom plants in shallow streams, only for macroscopic animals living on outside of plants

Procedure

1 Set sampler carefully over plants to be examined; settle horizontal frame firmly on bottom.

2. As stream water flows over horizontal frame and into net, wash plants thoroughly dislodging animals and allowing them to be carried by current into net.

3 Secure catch and treat as described elsewhere (p. 322) for other samples taken with sampler.

4. Express results in terms of number, weight or volume of animals per square meter of stream bottom

General Considerations

a. Care must be taken that animals not related to the plants are prevented from being drifted into the net by the current.

b If desirable, the plants may be saved from the area examined, drained of excess water, weighed (wet weight), and the results expressed in terms of the number, weight or volume of animals per pound of plants involved.

HESS METHOD FOR FLOATING VEGETATION

EQUIPMENT Cylinder of heavy galvanized iron, 6 in high, having top area of 1 sq. ft, and bottom covered with No 40 brass screening, wooden paddle.

SUITABILITY. Suitable for securing samples from floating mats of aquatic vegetation, for macroscopic animals living on outside of plants.

Procedure

1. Slip sampler under mat of vegetation to sampling position, bring sampler up against lower surface of mat and lift slightly above water.

2 Cut out circular sample by striking all around edge of sampler with wooden paddle.

3 Wash animals from vegetation so collected into sampler, and transfer them to collecting jar, transfer plants to large paper bag, transport to laboratory for analyses.

4 Sort, identify, enumerate, and express in terms of number, weight, or volume per square meter of water surface, also if desired, drain plants and express results in terms of number, weight or volume of animals per unit of wet weight of plants involved

WASHING METHOD

SUITABILITY. Suitable only for general purposes in which results of but approximate accuracy are acceptable

Procedure

1. By any means suitable and convenient for the situation involved, sever connections of plants from bottom and lift slowly and carefully to surface but *not out of water.*

2 Submerge a 30-mesh screen of type described on p 186 and slip under plants as they approach surface, lift screen and contained plants and discharge all contents into large tub

3. Repeat this form of collection until desired quantity of plants is secured. Transfer to shore for washing and weighing.

4 Pile plants on a 30-mesh screen and allow to drain for 5 min. Then transfer all contents of screen to large tub partly filled with clean tap water and wash plants *thoroughly* displacing all adhering organisms and extraneous materials.

5 Lift plants from water, pile on screen and allow to drain for 5 min ; weigh plants to secure their *wet weight.*

6. Pour contents of tub through a 30-mesh screen. With additional amounts of tap water, wash residue in screen until all extraneous materials which will pass through meshes have been eliminated

7 Sort, isolate and count organisms in screen residue by method described on p 303

8 Compute number of organisms per pound of wet weight of plants, or if preferred, allow excess water to drain off organisms by method described on p 304, measure volume, and compute volume of total organisms (or of various kinds of organisms) per pound of wet weight of plants, or, if desirable, weigh drained (p 304) organisms, in total or by different kinds, and compute number of selected weight units of organisms per weight unit of wet weight of plants

General Considerations

a In this method no account can be taken of any organisms *within* the plants concerned.

b The size of the screen employed determines the size of invertebrates lost through the meshes

c. Plants must be so collected that samples are representative of the plant beds involved.

d The operator must be on guard against losses of invertebrates which may occur while plants are being hauled up through the water Such loss may be detected and measured by the use of a fine-mesh "umbrella net" swung under the plants when first detached from bottom, then brought to the surface immediately below the plant mass

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Appendix

LINES

So numerous and varied is the need for lines in limnological work that careful choices are necessary if dependable results are to be obtained

Graduated Ropes

For work in inland waters graduated ropes have many uses To be satisfactory a rope must be strong, flexible, closely plaited or twisted, durable, free from undue initial stretching, and must lend itself to some simple system of permanent graduation Companies dealing in cordage supply information and samples on application Rarely will graduated ropes of diameter greater than ⅜ in be needed, smaller sizes are sometimes required for special purposes Good linen or hemp ropes are usually acceptable. Certain kinds and sizes of "tiller rope" may be useful Cotton cord must be carefully inspected and tested Best-grade sash cord (window-weight cord), sizes No 6, 7, and 8, is satisfactory However, since not all sash cord is of equal quality, samples should be secured and tested in advance. White sash cord is preferable to colored or spotted since it does not obscure graduation marks Ordinary clothes-line rope and similar loosely woven cotton lines should be avoided All ropes, even under the best of care, deteriorate because of wear and aging and must be replaced from time to time

Since all ropes will stretch and shrink, new ones, prior to graduation, should be treated as follows. Stretch the line tightly between two trees or posts, or wrap tightly about an oil drum or other cylindrical object of convenient size, wet thoroughly and allow to dry, restretch or rewind to take up slack and again wet and allow to dry, repeat treatment until the stretch seems to be out, but use care not to overstretch.

When a rope is ready to be graduated it should be laid out on the floor of a long corridor or on a clean concrete walk, pulled straight and stretched with a tension slightly in excess of that representing the weight of the instruments to be used on it, and then securely fastened at each end. Begin at one end to measure off the desired intervals with a previously tested steel tape or some other instrument of linear measure, using the desired units (feet or meters), and install the permanent markers of the selected graduation system The zero mark should be at least one foot from the end of the rope in order to provide a tie-on margin.

Various systems of marking graduations may be used. Whatever the scheme of graduation, good visibility and ease of reading are prime requisites If ropes are to be used in operations which do not require the use of

metal messengers, the intervals may be marked in one of the conventional ways by knotting and threading pieces of cloth (white at all intervals except the fifth which is red and red at every fifth thereafter) through the meshes or strands of the rope However, this method can not be used for ropes on which messengers must slide and since many instruments require messengers some other effective method of graduation must be provided The writer uses the following scheme the desired intervals are marked by a thorough application, with a small brush, of waterproof black ink (Higgins Eternal, or Higgins India), making certain that the ink soaks deep into the rope. When used on white sash cord, this affords an easily recognizable mark, and while its distinctness is dimmed somewhat in a dry rope which has had considerable use, it becomes distinct again when wet One thorough treatment with the ink will usually suffice to last through the life of the rope Renewal may be needed when ropes have an unusual amount of messenger or handling wear. A simple system of long marks, short marks, and groups of long and short marks can be devised which will enable the operator to read directly the various levels. In the case of marks, or of groups of marks of considerable length, the interval should be correct at the middle point

It must not be expected that ropes, constructed as described above, will remain accurate without further attention There is always the possibility that they will shrink in length when coiled and stored for long periods of time They may even show some shrinkage if coiled and dried after ordinary use in the field Therefore, graduated ropes should be frequently inspected—wet them, pull them out straight on a long flat surface and test them for accuracy along the entire length Usually, if a rope is found to be short of the expected value, the shrinkage has been uniform throughout the entire length and correction can be made by pulling the rope until the shrink is removed, after which the rope will probably remain correct for that day's work or perhaps longer However, when careful work is required, it will be much safer to test the ropes both at the beginning and at the end of the day's work This checking may be done with a tape or meter stick, but a more convenient way is to mark off permanent intervals with copper tacks on the boat deck, dock, or laboratory floor.

During a period of active use, keep graduated ropes submerged in water If for any reason this procedure cannot be followed, thoroughly soak them in water for about an hour and then test for accuracy before using

Every graduated rope should bear some means of identification, preferably a serial number. Such identification number should be attached to the end opposite the zero end of the rope The writer uses 3 × 3-cm squares of heavy canvas on which the identification number is written boldly in black waterproof ink The square is then soaked in melted paraffin and attached by a strong, paraffined cord sewed into the rope

Metal Lines

Metal lines have both advantages and disadvantages Their principal point of superiority is in the fact that they do not stretch or shrink (temperature effect usually negligible) They may also combine small bulk with greater length of life if properly cared for Obvious disadvantages are the following points (1) ordinarily they must be used on a reel or drum in order to prevent kinking or twisting, (2) they should be of nonrust metal, (3) it is difficult to attach graduation marks if graduation has not been built into the line by the maker, (4) use by hand is slow, uncomfortable, and sometimes impracticable, and (5) they are likely to be expensive.

Probably the best of all metal lines are the stranded wire and the piano wire which have been used extensively for sounding in deeper waters, but they can be operated only on a revolving drum and, in lieu of graduations on the line, depths must be determined by a recording dial geared to the drum mechanism For soundings in depths of 200–500 fathoms, the U S Coast and Geodetic Survey uses a stranded wire composed of seven tightly twisted strands of double-galvanized wire, each No 24 B and S gage, and with a breaking strength of not less than 500 lb It is obtainable in sealed tins containing 300-fathom lengths For greater depths, steel piano wire, No 21 B and S gage, is employed For some purposes graduated steel tapes may be used but they require much care to prevent rusting, and unless they are quite narrow, messengers cannot slide on them. Special tapes, suitable for limnological purposes, are expensive Tapes can be used only by winding and unwinding on a reel Metal fishing lines have been tried, but usually with little success since they also must be used on a reel, can be graduated with difficulty, and most, if not all, of them kink too readily. Small brass chains, graduated by solder marks in links or by soldering small circular stamped brass plates to links, have been used with some success but have the disadvantage of being uncomfortable to use by hand

Small, flexible, multiple-strand wire cables of ⅛-in diameter or less may be used on a hand reel They should be galvanized to prevent rusting The smaller sizes will probably be preferred, if they have adequate tensile strength, because of their greater flexibility and lighter weight Such wire cables may be graduated by marking them with barn-red paint

Combination Lines

Lines can be purchased from cordage and other supply companies which combine metal and rope in various ways, as for example, in some instances small copper wire strands are interwoven with the strands of the rope, in other kinds, the rope is woven about a centrally located copper wire. Such a combination increases the tensile strength of the rope and practically eliminates stretching or shrinking For lead-line sounding, the

U.S Coast and Geodetic Survey had adopted a line with wire center and finds that best results have been obtained with one known as Sampson mahogany tiller rope, size No 8, a waterproof solid braided rope with phosphor bronze wire center ("Hydrographic Manual," 1928, p 44) Such a line can be graduated in the usual ways However, when the interwoven-strand types are used for limnological purposes, sooner or later the wire strands break, thus defeating the purpose of such lines and also making them very bad for handling because of the projecting broken ends of the wire Combination metal-fabric lines last longer if used on drums or reels.

Lines for Heavy Equipment

Heavy samplers, dredges and similar equipment may demand stronger lines than those mentioned in the preceding section If such apparatus does not require the use of a messenger, lines of larger size are usable If messengers are required, a smaller line of relatively high tensile strength is necessary and must be specially selected if a rope is to be used, but a small wire cable will probably be preferable

Heavy instruments carrying a heavy load should be handled with a drum lift if possible Under these circumstances a well-chosen, small-diameter, nonrust wire cable is suitable Manufacturers of wire cables will supply samples and full information The variety of wire cables made for commercial purposes is so great that almost any desired type can be secured

If heavier instruments are to be used by hand, metal cables are ill suited for such work As a general utility article, a good-grade Manila rope of ½- to ¾-in size will be found adaptable, durable, and easy to handle.

Wire cables of properly selected kinds and sizes are useful for many purposes, particularly for anchors, floats, buoys, and work rafts, but are expensive and handle with some difficulty. Ropes are in more general use. Good Manila rope of appropriate size is very serviceable, but its life in water is relatively short unless it has been impregnated with paraffin, linseed oil and paraffin, or some other waterproofing substance The well-known tarring treatment employed by commercial fishermen and others is very effective but ropes so prepared are disagreeable to handle and possess other objections for scientific work.

Small Lines

The limnologist has innumerable needs for small lines. They may be chosen to suit his own preferences and uses from the great variety of cordage on the market Linen twines and cords are very useful. The well-known fish-cord, in its various sizes, is convenient When soaked in melted soft paraffin, its life is considerably prolonged

Table 1

EQUIVALENT VALUES

Length

1 inch = 25 40 millimeters
= 2.54 centimeters
1 foot = 0 305 meter
= 30 5 centimeters
1 yard = 3 feet
= 0.914 meter
1 rod = 16 5 feet
= 5.5 yards
1 mile (statute) = 63,360 inches
= 5280 feet
= 1760 yards
= 320 rods
= 1609 meters
= 1.609 kilometers
= 0 867 geographic mile
1 millimeter = 0 0393 inch
1 centimeter = 0.393 inch
1 meter = 39 37 inches
= 3.281 feet
= 1 0936 yards
= 0 000621 mile
1 kilometer = 3281 feet
= 1000 meters
1 chain (Gunter's) = 792 inches
= 66 feet
= 4 rods
= 0 0125 mile
1 link (Gunter's) = 7.92 inches
= 0 04 rod
1 chain (engineer's) = 100 feet
1 link (engineer's) = 1 foot

Table 1—(Continued)

EQUIVALENT VALUES

Depth

1 fathom = 6 feet
 = 1.829 meters

Area

1 square inch = 6.42 square centimeters
1 square foot = 929.03 square centimeters
1 square yard = 0.836 square meter
1 acre = 43,560 square feet
 = 4840 square yards
 = 160 square rods
 = 10 square chains (Gunter's)
 = 0.4047 hectare
1 section = 640 acres
 = 1 square mile
1 square mile = 640 acres
 = 259 hectares
 = 2.59 square kilometers
1 square millimeter = 0.0015 square inch
1 square meter = 10.758 square feet
1 hectare = 10,000 square meters
 = 2.5 acres (approximately)

Volume

1 cubic inch = 16.386 cubic centimeters
1 cubic foot = 28,316 cubic centimeters
 = 7.48 gallons
 = 0.0283 cubic meter
1 cubic yard = 0.7646 cubic meter
1 acre-foot = 325,850 gallons
1,000,000 cubic feet = 22.95 acre-feet
1 cubic centimeter = 0.061 cubic inch
1 cubic meter = 35.314 cubic feet
 = 1.308 cubic yards

Table 1–(Continued)

EQUIVALENT VALUES

Capacity

1 U S pint = 473 18 cubic centimeters

1 U S. quart = 2 pints

= 946 cubic centimeters

= 0 946 liter

1 U S gallon = 231 cubic inches

= 4 quarts

= 3784 cubic centimeters

= 3 784 liters

1,000,000 gallons = 3 07 acre-feet

1 liter = 61 027 cubic inches

= 2 11 pints

= 1 0567 quarts

= 1000 cubic centimeters

Miscellaneous

1 atmosphere pressure = about 15 pounds per square inch

= about 1 ton per square foot

= about 1 kilo per square centimeter

Angles

1 circumference = 360 degrees

1 degree = 60 minutes

1 minute = 60 seconds

Table 2

MATHEMATICAL FORMULAS

Given	*Sought*	*Formula*
Triangle		
1. Base (b) and altitude (a')	Area (a)	$a = \frac{ba'}{2}$, or $= b\left(\frac{a'}{2}\right)$
2. Area (a) and base (b) or altitude (a')	Base (b), or altitude (a')	$b = \frac{2a}{a'}$, or $a' = \frac{2a}{b}$
3. Three sides (d, d', d'')	Area (a)	Let s = sum of three sides, then $a = \sqrt{\left(\frac{s}{2}-d\right)\left(\frac{s}{2}-d'\right)\left(\frac{s}{2}-d''\right)\left(\frac{s}{2}\right)}$
4. Base (b) and perpendicular (p) of right-angle triangle	Hypotenuse (h)	$h = \sqrt{b^2 + p^2}$
5. Base (b) or perpendicular (p) and hypotenuse (h) of right-angle triangle	Base (b), or perpendicular (p)	$b = \sqrt{h^2 - p^2}$, or $p = \sqrt{h^2 - b^2}$
Trapezoid		
6. Sides (s and s') and altitude (a')	Area (a)	$a = a'\left(\frac{s + s'}{2}\right)$
Trapezium		
7. Diagonal (d) and perpendiculars (p and p') to diagonal drawn from vertices of opposite angles	Area (a)	$a = d\left(\frac{p + p'}{2}\right)$
Circle		
8. Radius (r)	Circumference (c)	$c = 2\pi r$
9. Circumference (c)	Radius (r)	$r = \frac{2\pi}{c}$
10. Radius (r)	Area (a)	$a = \pi r^2$
Sphere		
11. Radius (r)	Surface (s)	$s = r^2(4\pi)$
12. Radius (r)	Volume (v)	$v = r^3\left(\frac{4\pi}{3}\right)$

Table 2–(Continued)

MATHEMATICAL FORMULAS

Given	*Sought*	*Formula*
Cylinder		
13. Radius (r) and altitude (a')	Convex surface (s), or volume (v)	$s = a'(2\pi r)$, or $v = a'(\pi r^2)$
Cone		
14. Radius (r) and altitude (a')	Volume (v)	$v = \frac{a'}{3}(\pi r^2)$
15. Radius (r) and slant height (h)	Convex surface (s)	$s = \frac{h}{2}(2\pi r)$
Frustrum of Cone		
16. Areas of both bases (b and b') and altitude (a')	Volume (v)	$v = \frac{a'}{3}(b + b' + \sqrt{bb'})$
17. Circumferences (c and c') and slant height (h)	Convex surface (s)	$s = \frac{h}{2}(c + c')$

Table 3

FEET TO METERS*

Feet	*0*	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*
0	0 000	0 305	0 610	0 914	1 219	1 524	1 829	2 134	2 438	2 743
10	3 048	3 353	3 658	3 962	4 267	4 572	4 877	5 182	5 486	5 791
20	6 036	6 401	6 706	7 010	7 315	7 620	7 925	8 229	8 534	8 839
30	9 144	9 449	9 753	10 058	10 363	10 668	10 972	11 277	11 582	11 887
40	12 192	12.496	12 801	13 106	13 411	13 716	14 020	14 325	14 630	14 935
50	15 239	15 544	15 849	16 154	16 459	16 763	17 068	17 373	17 678	17 983
60	18 287	18 592	18 897	19 202	19 507	19 811	20 116	20 421	20 726	21 031
70	21 335	21 640	21 945	22 250	22 555	22 859	23 164	23 469	23 774	24 079
80	24 383	24 688	24 993	25 298	25 602	25.907	26 212	26 517	26 822	27 126
90	27 431	27 736	28 041	28 346	28 651	28 955	29 260	29 565	29 870	30 174
100	30 479	30 784	31 089	31 394	31 698	32 003	32 308	32 613	32 918	33 222

*Length in feet expressed in left vertical column and in top horizontal row, corresponding lengths in *meters* in body of table

Table 4

METERS TO FEET*

Meters	*0*	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*
0	0 00	3 28	6 56	9 84	13 12	16 40	19 69	22 97	26 25	29 53
10	32 81	36 09	39 37	42 65	45 93	49 21	52 49	55 78	59 06	62 34
20	65 62	68 90	72 18	75 46	78 74	82 02	85 30	88 58	91 87	95 15
30	98 43	101 71	104 99	108 27	111 55	114 83	118 11	121 39	124 67	127 96
40	131 24	134 52	137 80	141 08	144 36	147 64	150 92	154 20	157 48	160 76
50	164 04	167 33	170 61	173 89	177.17	180 45	183 73	187 01	190 29	193 57
60	196 85	200 13	203 42	206 70	209 98	213 26	216 54	219 82	223.10	226 38
70	229 66	232 94	236 22	239 51	242 79	246 07	249 35	252 63	255 91	259 19
80	262 47	265 75	269 03	272 31	275 60	278 88	282 16	285 44	288 72	292 00
90	295 28	298 56	391 84	305 12	308 40	311 69	314 97	318 25	321 53	324 81
100	328 09	331 37	334 65	337 93	341 21	344 49	347 78	351 06	354 34	357 62

*Length in meters expressed in left vertical column and in top horizontal row, corresponding lengths in *feet* in body of table

Table 5

TEMPERATURES—CENTIGRADE TO FAHRENHEIT*

Temp ° C	*0*	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*
0	32.0	33.8	35.6	37.4	39.2	41.0	42.8	44.6	46.4	48.2
10	50.0	51.8	53.6	55.4	57.2	59.0	60.8	62.6	64.4	66.2
20	68.0	69.8	71.6	73.4	75.2	77.0	78.8	80.6	82.4	84.2
30	86.0	87.8	89.6	91.4	93.2	95.0	96.8	98.6	100.4	102.2
40	104.0	105.8	107.6	109.4	111.2	113.0	114.8	116.6	118.4	120.2
50	122.0	123.8	125.6	127.4	129.2	131.0	132.8	134.6	136.4	138.2

*Temperatures in degrees Centigrade expressed in left vertical column and in top horizontal row, corresponding temperatures in degrees Fahrenheit in body of table

Table 6

TEMPERATURES—FAHRENHEIT TO CENTIGRADE*

Temp ° F	*0*	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*
30	−1 11	−0 56	0 00	0 56	1.11	1.67	2 22	2 78	3 33	3 89
40	4 44	5 00	5 56	6 11	6 67	7.72	7 78	8 33	8 89	9 44
50	10 00	10 56	11 11	11 67	12 22	12 78	13 33	13 89	14 44	15.00
60	15 56	16 11	16 67	17 22	17.78	18 33	18 89	19 44	20 00	20 56
70	21.11	21 67	22 22	22 78	23 33	23 89	24 44	25.00	25 56	26 11
80	26.67	27 22	27 78	28 33	28.89	29 44	30 00	30 56	31 11	31 67
90	32 22	32 78	33 33	33 89	34 44	35 00	35 56	36 11	36 67	37 22
100	37 78	38 33	38 89	39 44	40 00	40 56	41 11	41 67	42 22	42 78

*Temperatures in degrees Fahrenheit expressed in left vertical column and in top horizontal row, corresponding temperatures in degrees Centigrade in body of table

Table 7

EFFECT OF TEMPERATURE UPON DENSITY OF WATER*

From Birge

I *Temperature* °C	II *Density*	III *Difference*	IV *Relative Difference for 1° C*	V *Ergs*
0	0.999868	+0.000059	7.38	0.0491
1	0.999927	+0.000041	5.12	0.0342
2	0.999968	+0.000024	3.00	0.0200
3	0.999992	+0.000008	1.00	0.0067
4	1.000000	—0.000008	1.00	0.0067
5	0.999992	—0.000024	3.00	0.0200
6	0.999968	—0.000039	4.88	0.0325
7	0.999929	—0.000053	6.62	0.0441
8	0.999876	—0.000068	8.50	0.0566
9	0.999808	—0.000081	10.12	0.0675
10	0.999727	—0.000095	11.88	0.0791
11	0.999632	—0.000107	13.38	0.0891
12	0.999525	—0.000121	15.12	0.1008
13	0.999404	—0.000133	16.62	0.1108
14	0.999271	—0.000145	18.12	0.1208
15	0.999126	—0.000156	19.50	0.1299
16	0.998970	—0.000169	21.12	0.1408
17	0.998801	—0.000179	22.38	0.1491
18	0.998622	—0.000190	23.75	0.1583
19	0.998432	—0.000202	25.25	0.1683
20	0.998230	—0.000211	26.38	0.1758
21	0.998019	—0.000222	27.75	0.1849
22	0.997797	—0.000232	29.00	0.1993
23	0.997565	—0.000242	30.25	0.2016
24	0.997323	—0.000252	31.50	0.2099
25	0.997071	—0.000261	32.62	0.2174
26	0.996810	—0.000271	33.88	0.2257
27	0.996539	—0.000280	35.00	0.2332
28	0.996259	—0.000288	36.00	0.2399
29	0.995971	—0.000298	37.25	0.2482
30	0.995673			

*See note to table on facing page

Note for Table 7

*Column I indicates temperature in degrees Centigrade, column II shows the density of pure water Note that the numbers in columns III to V are not on a level with those in columns I to II but are opposite the spaces between these numbers Column III shows the differences between the successive numbers of the previous column and indicates the change in density caused by a temperature change of 1° The significant figures also show the difference in weight, in milligrams, between a liter of water at any given temperature and at a temperature 1° lower Thus, a liter of water at 10° weighs 81 mg less than one at 9° These numbers express the differences in density and weight which for a temperature difference of 1° (1) enable a layer of water to set up convection currents if it lies above a warmer stratum and (2) enable a stratum of water, warmer above and cooler below, to resist mixture attempted by mechanical agents Column IV, the convection capacity and the thermal resistance to mixture corresponding to the temperature difference of 1° at 4° to 3° or 4° to 5°, is taken as unity, and the relative value is given for the same difference at higher or lower temperatures At 10°, its value is more than ten times greater than at 4°, at 15°, it has increased eighteenfold, and at 30°, it is more than thirty-seven times larger than at 4°. Column V contains a statement of work in decimals of an erg which would be required to mix a column of water 1 sq cm in area, 1 m. high, in which the temperature gradient is uniform and whose upper and lower surfaces differ in temperature by 1° (Explanation largely quoted from Birge)

Table 8

AMOUNT OF DISSOLVED OXYGEN IN WATER AT DIFFERENT TEMPERATURES WHEN EXPOSED TO AN ATMOSPHERE CONTAINING 20.9 PER CENT OF OXYGEN UNDER A PRESSURE OF 760 MM INCLUDING PRESSURE OF WATER VAPOR*

Temp °C	*Parts per Million*	*Cc per liter (at 0° C and 760 mm)*	*Temp* °C	*Parts per Million*	*Cc per liter (at 0° C and 760 mm)*
0	14.62	10.23	16	9.95	6.96
1	14.23	9.96	17	9.74	6.82
2	13.84	9.68	18	9.54	6.68
3	13.48	9.43	19	9.35	6.54
4	13.13	9.19	20	9.17	6.42
5	12.80	8.96	21	8.99	6.29
6	12.48	8.73	22	8.83	6.18
7	12.17	8.52	23	8.68	6.07
8	11.87	8.31	24	8.53	5.97
9	11.59	8.11	25	8.38	5.86
10	11.33	7.93	26	8.22	5.75
11	11.08	7.75	27	8.07	5.65
12	10.83	7.58	28	7.92	5.54
13	10.60	7.42	29	7.77	5.44
14	10.37	7.26	30	7.63	5.34
15	10.15	7.10			

*Reprinted by permission from "The Microscopy of Drinking Water," by Whipple, Fair, and Whipple, published by John Wiley & Sons, Inc.

Table 9

GRADES AND SIZE RANGES OF SILK BOLTING CLOTH

Grade	*Range of Sizes*
Standard	Nos 0000–25
X quality	Nos 6–17
XX quality	Nos 0000–16
XXX quality	Nos 6–18
Grit gauze	Nos 14–72
XXX Grit gauze	Nos 14–72

Table 10

WENTWORTH'S CLASSIFICATION OF COARSER SEDIMENTS BASED UPON SIZE OF PARTICLES

Diameter of Particle in mm	*Name Applied to Particle*
More than 256	Boulder
256–64	Cobble
64–4	Pebble
4–2	Granule
2–1	Very coarse sand
1–0.5	Coarse sand
0.5–0.25	Medium sand
0.25–0.125	Fine sand
0.125–0.062	Very fine sand
0.062–0.004	Silt
Less than 0.004	Clay

Table 11

WENTWORTH GRADE SCALE, $\sqrt{2}$ SCALE, $\sqrt[4]{2}$ SCALE, CORRESPONDING TYLER SIEVE OPENINGS AND MESH, AND CORRESPONDING MESH OF U S. SIEVE SERIES*

Wentworth Grade Scale (mm)	*The Openings Increase in the Ratio of*		*Tyler Screens*		*U S Sieve Series, Mesh*
	$\sqrt{2}$ or 1 414 mm	*$\sqrt[4]{2}$ or 1 189 mm*	*Mm.*	*Mesh*	
4	4.00	4 00	3 96	5	5
Granule		3 36	3 33	6	6
	2.83	2 83	2 79	7	7
		2 38	2.36	8	8
2	2 00	2 00	1.98	9	10
Very coarse sand		1.68	1 65	10	12
	1 41	1 41	1.40	12	14
		1 19	1.17	14	16
1	1 00	1 00	0 991	16	18
Coarse sand		0.840	0 833	20	20
	0 707	0 707	0 701	24	25
		0 595	0 589	28	30
0 500 (½)	0 500	0 500	0.495	32	35
Medium sand		0.420	0 417	35	40
	0 354	0 354	0 351	42	45
		0 297	0.295	48	50
0 250 (¼)	0 250	0 250	0.246	60	60
Fine sand		0 210	0.208	65	70
	0 177	0.177	0.175	80	80
		0.149	0.147	100	100
0.125 (⅛)	0 125	0.125	0.124	115	120
Very fine sand		0.105	0.104	150	140
	0.088	0 088	0.088	170	170
		0 074	0 074	200	200
0.062 (1/16) Silt	0 062	0 062	0 061	250	230

*Reprinted by permission from "Methods of Study of Sediments," by Twenhofel and Tyler, published by McGraw-Hill Book Co

Table 12

AVERAGE APERTURE SIZE OF STANDARD GRADE DEFOUR BOLTING SILK*

Silk No	*Meshes per Inch*	*Size of Aperture (mm)*	*Silk No*	*Meshes per Inch*	*Size of Aperture (mm)*
0000	18	1.364	10	109	0.158
000	23	1.024	11	116	0.145
00	29	0.752	12	125	0.119
0	38	0.569	13	129	0.112
1	48	0.417	14	139	0.099
2	54	0.366	15	150	0.094
3	58	0.333	16	157	0.086
4	62	0.318	17	163	0.081
5	66	0.282	18	166	0.079
6	74	0.239	20	173	0.076
7	82	0.224	21	178	0.069
8	86	0.203	25	200	0.064
9	97	0.168			

*Reprinted with permission from "The Oceans, Their Physics, Chemistry and General Biology," by Sverdup, Johnson and Fleming, published by Prentice-Hall, Inc

Table 13

RELATION OF ANGLES OF WILD'S PLATE TO WIND VELOCITY*

Angle† in Degrees	0	4	15.5	31	45.5	58	72	80.5
Wind Velocity in Meters per Second	0	2	4	6	8	10	14	20
Beaufort Scale	0	2	3	4	5	6	7	8

*Reprinted with permission from "Physical Climatology," by Landsberg, published by Gray Printing Company

†Angles measured from the perpendicular.

SOURCES OF HYDROGRAPHIC MAPS AND HYDROGRAPHIC INFORMATION

This list is suggestive only and claims no completeness. See elsewhere (p 1) for caution on unsuitability for limnological purposes of some maps made by agencies whose interests lie elsewhere

Federal

Coast and Geodetic Survey
Geological Survey
Lake Survey
Forest Service
Fish and Wildlife Service
Tennessee Valley Authority
Bureau of Reclamation
Mississippi River Commission

Aid may be secured concerning maps published by these and other federal offices by applying to the U S Map Information Office, Department of Interior Building, Washington, D.C.

State

Geological Surveys
Departments of Conservation
Biological Surveys
Highway Departments

Miscellaneous

City Engineers' Offices, Water Supply, Sewage Disposal
Water Power organizations
Irrigation organizations
Recreational systems
Sportsmen's preserves
Reservoir lake developments
Publications of inland biological stations

In limnological descriptions, geographical location of streams and lakes must be expressed with certainty. Names alone cannot be depended upon save in the instances of large bodies of water. Names are sometimes wholly local and different ones may be used for the same water. Therefore some other means must be used. Ordinarily this can best be done through the use of conspicuous, permanent, and well-known physical features, an adopted system of land survey, an established system of political subdivisions, or a

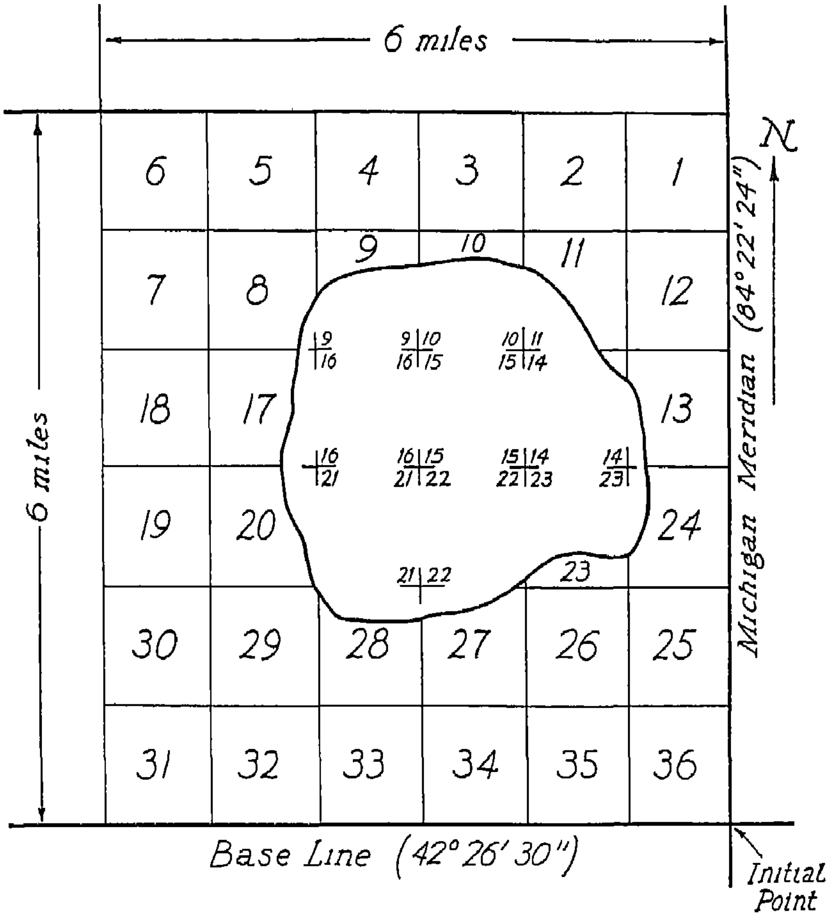


FIG. 91 Diagram of a congressional township showing method of numbering sections. Outline of lake within township shows numbering system for sections occupied wholly or in part by water.

judicious combination of these three It is often preferable to base the description of inland lakes and streams upon the framework of the U S Public Land Survey in much the same way that tracts of land are specified for legal purposes In this system, the congressional township is the basic unit. It is 6 miles square and contains 36 *sections* (approximately 36 sq mi) Each section is designated by a number and the system of numbering is shown in Fig 91 Townships are numbered into *ranges* which extend north and south and into *tiers* which extend east and west These ranges and tiers are related to an *initial point* formed by the intersection of the *principal meridian* and the *base line* of the whole area concerned Principal meridians and base lines are often indicated on the larger geographic maps, ranges and tiers of townships are shown only on local, detailed maps According to this system the imaginary lake shown in Fig. 91 is located as follows Sections 15, 16, 21, 22, and portions of sections 9, 10, 11, 13, 14, 17, 20, 23, 24, 27, and 28, Township 1 North, Range 1 West of the Michigan Meridian (abbreviated T 1 N R 1 W Mich M) Further details concerning the system of U S Land Surveys can be secured by consulting a standard text on surveying, also from the "Manual of Instructions for the Survey of the Public Lands of the United States," Government Printing Office.

ACCESSORY EQUIPMENT

Plankton Trawl

The plankton trawl is usually used for the capture of plankters which occur very near the bottom. Fig. 92 shows the construction of this device The net is mounted on a metal collar which in turn is attached to a metal frame. A tow cord, tied to the frame, affords means of dragging this apparatus along the bottom The horizontal metal sheet protects the net against damage.

The plankton trawl is very useful in connection with qualitative study of plankton in streams. In running water the trawl is not dragged but instead is anchored in position, mouth upstream, and left there during the collection period When a coarser net is substituted for the fine-mesh bolting cloth of the plankton net, this device may be useful in the capture of those larger organisms which are carried downstream with the current and constitute much of what is called *stream drift.*

Field Kits

Portable field kits must be provided if equipment is to be properly guarded and if procedures are to be facilitated. Many different designs are required for diverse needs and the working limnologist must expect to plan and build cases for his own instruments since few such containers are available on the market

Chemical Kits Since in many chemical analyses water samples must be treated in the field to some safe point just as soon as they are secured, a

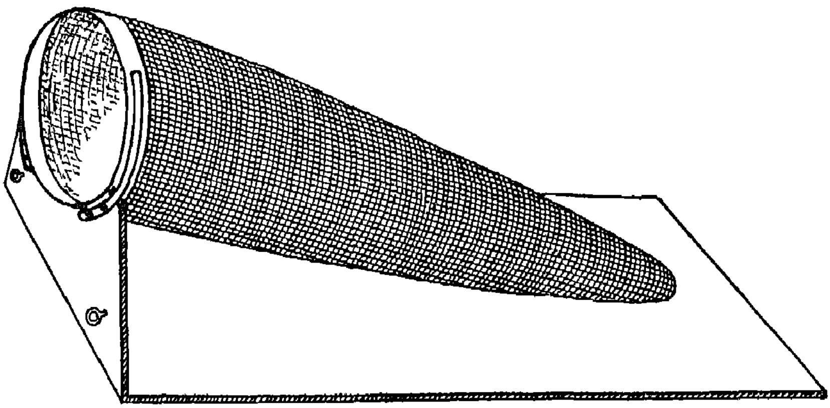


Fig 92. Side view of plankton trawl

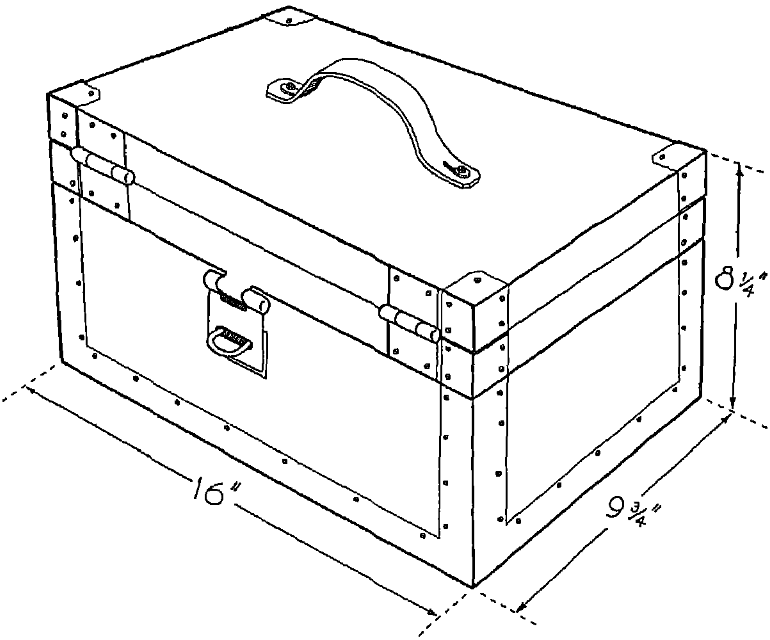


FIG 93 Field chemical kit in closed form.

chemical kit containing the necessary reagents, pipets, and other equipment should be supplied Figs. 93 and 94 represent the plan of a chemical kit developed in the writer's laboratory and used for many years It is constructed of half-inch well-seasoned basswood, all edges are bound with metal (sheet copper or galvanized iron), and the whole kit is covered, inside and outside, with several coats of good "outside" paint. The double-hinged lid provides housing for the numerous pipets Pipets are held in place by metal or rubber clips fastened to a removable board which fits into the lid space and is fastened to the walls of the lid by means of pegs and a spring catch. This board may be so constructed that pipets are supported on both surfaces

The kit portrayed in Fig 94 is designed to provide for equipment necessary for the routine field operations of analyses for dissolved oxygen, free carbon dioxide, alkalinities, hydrogen-ion concentration, and one or two others The numerous circular holes of same diameter hold a full set of pH colorimeter tubes Other compartments provide space for various bottles containing chemicals, indicators, necessary glassware, and general miscellany Brown and Flaten (1943) recently described a chemistry kit of somewhat different pattern which incorporates some features of the one discussed here

INSTRUMENT AND SAMPLE-BOTTLE KITS. Kits for equipment accessory

to chemical analyses, such as Kemmerer samplers, thermometers, graduated ropes, and miscellaneous articles, may be made of half-inch basswood to the following dimensions 27 × 9 × 8 in. Corners should be metal bound and the whole covered, both inside and outside, with at least three coats of "outside" paint The lid (top) is hinged along one side and fastened down on the other edge with two sturdy hasps, one near each end. The interior is divided lengthwise into two compartments by a partition about 3 in. high, thus making spaces for Kemmerer samplers. Above these spaces is a removable tray, 26 × 4¼ × 3¾ in, for other equipment. A strong leather handle is fastened to the top of the lid If heavy equipment is to be handled, the lid may require reinforcement

Kits for sample bottles may be made of the same materials and to the same dimensions as the instrument kit described above. The interior is

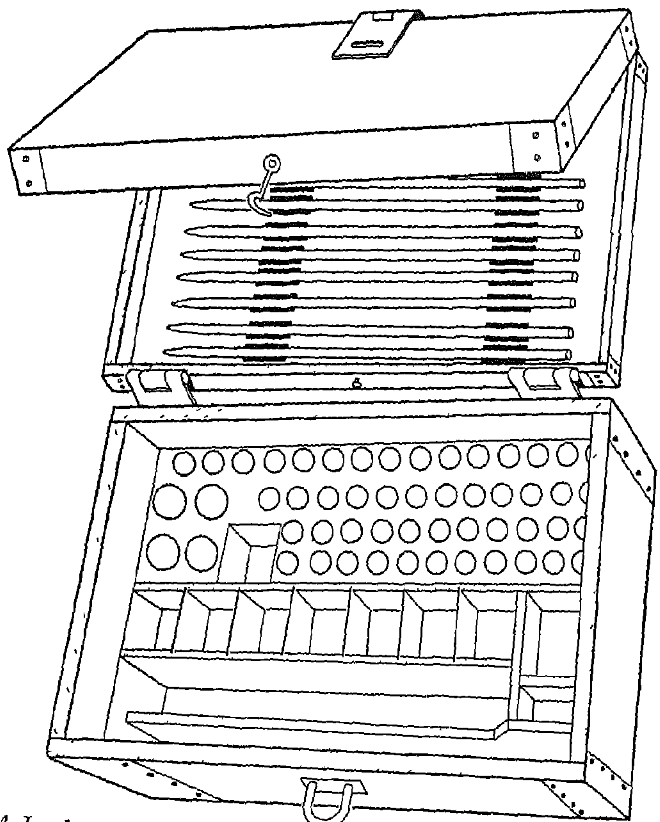


FIG. 94 Inside view of field chemical kit, showing pipets in holders on one surface of double lid; opposite surface of double lid also provided with holders (not shown in figure) for additional pipets.

divided into square compartments of size necessary to hold sample bottles These kits may have lids as described above, or for some purposes they may be made without lids but equipped with fasteners at each end so that one sample-bottle kit can be attached to the lower surface of the instrument kit and both carried as one unit. Rubber feet at each corner of the lower surface reduce possible shock and breakage Small holes in the bottom allow stray water to drain out, although they are no substitute for the necessary occasional complete drying of the interior These kits must also be thoroughly painted on all surfaces.

Ice Drill

Cutting of holes for sounding through ice cover is slow and costly in effort unless performed by some power-driven device Fig 95 shows the chief construction features of an electric ice drill designed by Brown and Clark (1939) and used extensively by the Institute for Fisheries Research, Michigan Department of Conservation, in winter lake mapping The principal specifications are as follows *Motor*—1928 Studebaker starting motor (one which turns to the right), *drill bit*—1¾-in. wood bit, *shaft*—⁹⁄₁₆-in diameter steel rod (length determined by maximum depth of ice), *starting switch*—Universal starting motor switch, *battery*—regular 19-plate automobile battery It is necessary to install a thrust bearing (*tb*) on the lower side of the motor Battery cables may be of any convenient length. This drill will bore through 2–3 in. of ice per sec. and one operator can make

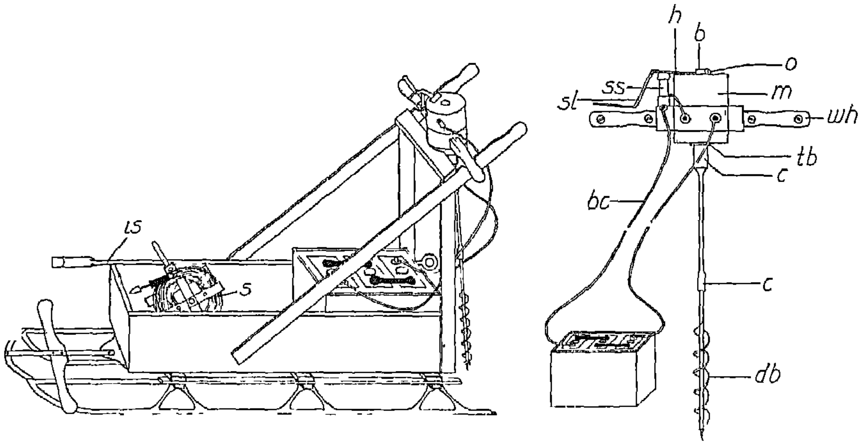


Fig 95. Electric ice drill designed by Brown and Clark for cutting sounding holes through ice in winter hydrographic mapping (*Left*) Transportation assembly (*Right*) Drill unit (*b*) Bearing (*bc*) Battery cable (*c*) Coupling (*db*) Drill bit (*h*) Hinge on starting lever. (*is*) Ice spud (*m*) Motor (*o*) Oil hole for upper bearing (*s*) Sounding line (*sl*) Starting lever (*ss*) Starting switch (*tb*) Thrust bearing (*wh*) Wooden handle. (Drawings by William L. Cristanelli)

300 or more sounding holes through thick ice in one day. At least one extra battery must be available if work is to be extended over two or more consecutive days since recharging will be necessary Because of its relatively light weight the drill is easily handled. For ease in operation and transportation the whole outfit is assembled on a sled as shown in Fig 95

Water Telescopes

Examination of objects submerged in shallow water is greatly facilitated by the use of so-called water telescopes Their essential feature is a plate of glass installed in some kind of frame which excludes water from its interior and is open at the top When the lowermost, glass-bearing portion is shallowly submerged in water and the operator looks down into the open end, visibility of objects in the water is increased by the elimination of surface interference Water telescopes may be made in many different forms to suit various needs Fig 96 represents three forms which serve general utility requirements a very serviceable type made by the simple process of replacing the bottom of an ordinary pail with a piece of

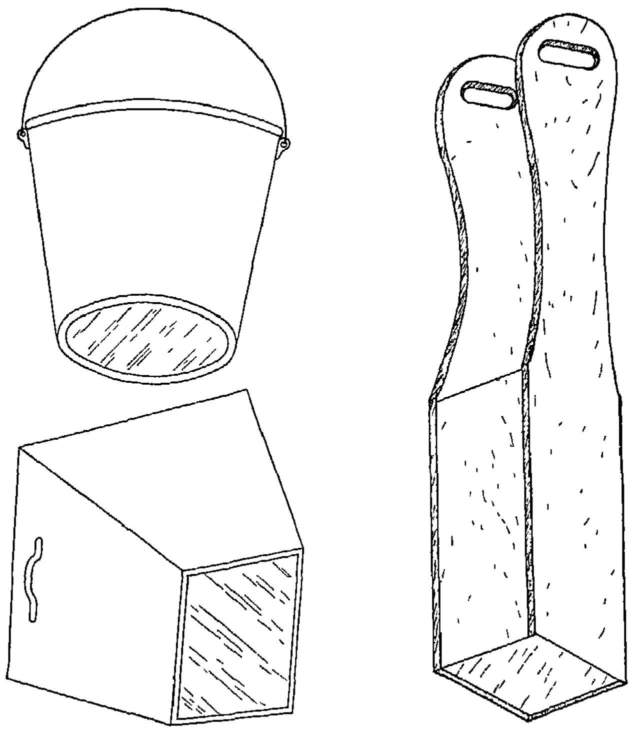


Fig 96 Three types of water telescope (*Top left*) Pail with glass bottom (*Bottom left*) Rectangular metal box with glass bottom (*Right*) Wooden frame with glass bottom

plain glass in a watertight installation, watertight installation of glass in the smaller end of a flaring metal (brass or galvanized iron) frame, square in cross section, a sheet of glass sealed into the lowermost end of a special wooden frame of the form shown in the figure. Glass should always be installed in such a way that a projecting rim of the frame offers some protection against breakage when the telescope is set end down on a hard support These types can be made in any metal shop and at small expense

An elongated water telescope for use over the sides of boats may be made by sealing glass into one end of a tube having a diameter about that of ordinary stove pipe and putting handles on each side at the other end.

Selected References

Brown, C J D, and O H Clark Winter lake mapping, *Michigan Conservation*, 8· 10-11, 1939 (Reprint of same paper issued to authors in enlarged form)

——, and C M Flaten "A Portable Field Chemistry Kit" 4 pp Spec Pub No 11, Limn Soc, Am, 1943

SOURCES OF LIMNOLOGICAL APPARATUS AND SUPPLIES

Limnological apparatus and supplies are so diverse that a working equipment must be assembled from many general sources. Certain items may be found in the catalogs of general scientific supply companies, but many others must be sought in highly specialized sources. In some instances it will be necessary to have instruments made to order. The Limnological Society of America published the extensive list of such sources indicated below.

Reference

"Sources of Limnological Apparatus and Supplies," rev. ed., 10 pp. Spec. Pub. No. 1, Limn. Soc. Am., 1939.

Correction Factors for Oxygen Saturation at Various Altitudes

Altitude Feet	Altitude Metres	Pressure mm	Factor
0	0	760	1 00
330	100	750	1 01
655	200	741	1 03
980	300	732	1 04
1310	400	723	1 05
1640	500	714	1 06
1970	600	705	1 08
2300	700	696	1 09
2630	800	687	1 11
2950	900	679	1 12
3280	1000	671	1 13
3610	1100	663	1 15
3940	1200	655	1 16
4270	1300	647	1 17
4600	1400	639	1 19
4930	1500	631	1 20
5250	1600	623	1 22
5580	1700	615	1 24
5910	1800	608	1 25
6240	1900	601	1 26
6560	2000	594	1 28
6900	2100	587	1 30
7220	2200	580	1 31
7550	2300	573	1 33
7880	2400	566	1 34
8200	2500	560	1.36

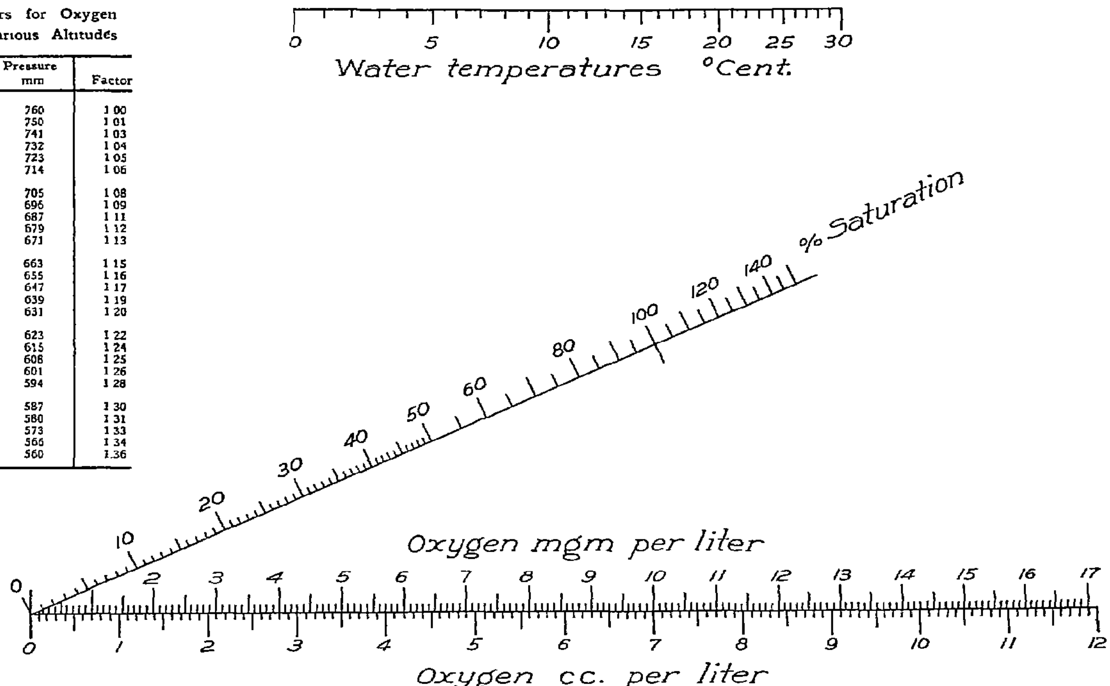


FIG 97 Rawson's nomogram for obtaining oxygen-saturation values at different temperatures and at different altitudes, also for transforming oxygen values from one kind of unit to another When a ruler, or preferably a dark-colored thread, is held so as to join an observed temperature on the upper scale with the observed dissolved-oxygen value on the lower scale, the values or units desired are read at points where the thread or ruler crosses the other scales The associated table supplies correction values for oxygen saturation at various altitudes, for example if 6 4 cc per liter of oxygen is observed in a sample from a lake having an altitude of approximately 500 m (1640 ft), the amount of oxygen which would be present at sea level under the same circumstances is found by multiplying 6 4 by the factor 1 06, giving the product 6 8, then the percentage saturation is determined by connecting 6 8 on the lower scale with the observed temperature on top scale and noting point of intersection on middle (diagonal) scale (Redrawn from Rawson, Spec Pub No 15, Limn Soc Am, 1944)

LITERATURE AIDS IN THE IDENTIFICATION OF PLANKTON

Selected List

References included here have been selected from the tremendous literature dealing with the taxonomy of plankton organisms Items chosen are those which are general in nature and which seem suited to the needs of the worker who is making an entry into the field of plankton identification It is believed that these references will also serve as a basis from which to secure leads into the more extensive literature For the most part, only recent works have been listed In a few instances certain unusually valuable old monographs have been included and are indicated by an *asterisk* (*) The inexperienced worker must not overlook the fact that these old works, while very helpful, are out-of-date in certain ways, as for example, in some details of nomenclature Completeness is not attempted in any group

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Index

INDEX

A

Accuracy required, ix
Aerial photographic mapping, 48
  of streams, 59
Alcohol, 271
Alidade, 19
Alkalinity, 214
  methyl orange, 215
  phenolphthalein, 215
  reagents, 214
Analyses, alkalinity, 214
  dry sieving, 192
  free carbon dioxide, 213
  gross, 190
  of bottom materials, 189
  of plankton concentrates, 279, 285, 286, 289, 290, 292, 295, 296
  oxygen, 206
  wet-and-dry sieving, 192
  wet sieving, 191
  with graded sieves, 191
Anchor gage, Stevens, 63
Anemometers, 169
  Biram, 169
  cup, 169
  Maxim pressure-plate, 172
  pressure-plate, 171
  pressure-tube, 170
  propeller or windmill, 169
  Wild's plate, 172
  Windikator, 171
Angle, exterior, 5
  interior, 5
Angles, equivalent values, 343
  improvised instrument for, 48
  simultaneously measured, 12
Ångstrom, *et al*, 161
Aniline dyes, 70
Antimony electrode, 223
Apparatus, sources of, 365
Appendix, 335–370
Aquatic plants, symbols for, 74, 75
Area, average ordinate rule, 90
  cross-section paper method, 87
  equivalent values, 342
  hatchet-planimeter method, 82
Area—(*Continued*)
  method of geometrical figures, 88
  planimeter method, 79
  Simpson's rule, 88
  weight method, 85
Areal standard unit method, 290
Atkins, *et al*, 161
Average ordinate rule, 90

B

Ball, Brown and, 179
Bank, descriptive abbreviations, 71
Basin, slope of, 96, 97
Bathythermograph, 112
Baylis turbidimeter, 136
Beach-pools, methods for, 20
Beak, 318
Beaufort wind scale, 172, 173
Bench mark, 61, 63
Bentzel velocity tube, 145
Biram anemometer, 169
Birge, 122, 123, 124
  and Juday, 167, 239
  cone net, 236
Bolting cloth, silk, 232
  aperture, size of, 355
  grades of, 233, 353
  installation in nets, 234
  pattern for nets, 234
  shrinking of, 233
Borers, peat, 185
Bottles, sampling, 206
Bottom, firmness of, 194
  marl, 320
  muck, 320
  profundal, methods for, 299
  rock surfaces, 320
  samplers, 175
  sampling, 186
  shoals, 320
  stream, 320
Bottom-fauna methods, 299
  core sampler, 306, 312
  Ekman dredge, 300
  gravimetric, 304
  Petersen dredge, 208, 312

Bottom-fauna methods—(*Continued*)
profundal, 299
volumetric, 304
Bottom materials, 175
analysis with graded sieves, 191
descriptive abbreviations, 71
dried samples, 190
final sample, 190
gross analysis, 190
mechanical analyses of, 189
quartering of samples, 189
wet samples, 190
Brown and Ball, 179
and Clark, 362
and Flaten, 360
Bryozoa, literature on, 370
Bumpus, Clarke and, 249
Buoy, 101, 102

C

Calcium chloride flotation method, 317
Calibration of equipment, x
Capacity, equivalent values, 343
Carbon dioxide, free, 213, 222
reagents, 213
Care of equipment, xv
field, xv
laboratory, xvii
screens, 189
Cell, photronic, 161
selenium rectifier, 162
Weston, 161, 167
Centrifuges, 260
Foerst electric, 256
hand, 260
plankton, 255
Chalk, 64
Chemical methods, 197, 199
Circle, formula for, 344
Cladocera, literature on, 369
Clarke, *et al*, 161
plankton sampler, 249
Closing nets, 246
operation of, 247
Closure, error of, 5
Coast and Geodetic Survey, U S, 61
Coefficient, net, 278
Color, apparent, 137
charts, 217
comparators, 220
filters, 162
glass-disk method, 138
glass standards, 219
in water, 137
indicators, 220
platinum-cobalt method, 137
Color—(*Continued*)
test papers, 220
true, 137
Colorimetric methods, color charts, 217
colored-glass standards, 219
comparators, 220
errors of, 221
for dissolved oxygen, 212
hydrogen-ion concentration, 217
indicators, 220
solution standards, 218
suitability of, 221
test papers, 220
Colors, application on maps, 69
crayon, 70
inks, 70
map, 69
water, 70
wax pencil, 69
Comparators, 220
Concentrates, analyses of plankton, 279, 285, 286, 289, 290, 292, 295, 296
Concentration zone, 309
Cone, formula for, 245
Cone net, Birge, 236
Considerations, introductory, ix
Contours, submerged, 68
Copepoda, literature on, 370
Core, analyses of, 306
apparatus for sectioning, 185
vertical sampler, 182
Core sampler, 182, 299, 306, 312
analyses of cores, 306
Correction of equipment, x
Cotton-disk filter, 264
Counting cell, 280
for bottom organisms, 307
Sedgwick-Rafter, 280
Young's, 328
Crane, lifting, 179
Crustacea, literature on, 369
plankton, 321
Cubic standard-unit method, 292
Cup anemometer, 169
Current, direction of, 154
meter, Ekman, 149
meters, mechanical, 147
Thrupp method, 149
velocity, 141
Curve, hypsographic, 94
Cyclops, 231
Cylinder, formula for, 345

D

Daphnia, 231
Darcy's tube, 142

Data, recording of, xiv
Datum, low-water, 69
Deep core sampler, 186
Dendy, inverting sampler, 315
Depth, equivalent values, 342
  profiles, 52
Depth of lakes, maximum, 78
  mean, 78
Diaptomus, 231
Differential count, plankton, 289
Diffusing glass, 162
Dilator, 145
Direction of water currents, 154
  Scott's vane method, 154
  streamer method, 155
Disk, Secchi, 159
  trial, 80
Dissolved oxygen, 206
  colorimetric, 212
  deficit, 212
  gradient, 213
  micro-Winkler method, 211
  Rideal-Stewart method, 207, 209
  Winkler method, 207
Dividers method, 93
Drawing table, 67
Dredge, Ekman, 176, 315
  Petersen, 178, 312
  Reighard, 309
  triangle, 310
Drift, stream, 359
Dyes, aniline, 70

E

Ekman, current meter, 149
  dredge, 176, 299, 300, 315
    analysis of samples, 303
    modification of, 302
Electric resistance thermometers, 117
Electrodes for pH measurements, 223
Electrolytes, 222
Electrometric methods, 217, 221
Embody, Goodrum and Edmond, 97
Embody's formula, 153
Equipment, care of, xv
  correction and calibration of, x
  duplicate, xiii
  marking of, xii
  storage of, xvii
Equivalent values, capacity, 343
  depth, area, and volume, 342
  length, 341
Ergs, 350
Errors, avoidance of, xiii
  in colorimetric methods, 221
  in copying, xiv
Errors—(*Continued*)
  in reversing thermometers, 106
  index, 40
  inherent, x
  natural, x
  of closure, 5
  of stadia surveys, 9
  personal, x
Exterior angle, 5

F

Feet to meters, 346
Field case, for glass tubes, 184
Field records, forms for, 7, 11, 16, 42, 54, 166
Filter paper, plankton method, 263
Filters, color, 162
  cotton-disk, 264
  plankton, 262
  sand, 263
  Schott, 162
  Sedgwick-Rafter, 265
  sling, 263
Float methods, rod, 151
  surface, 151
  tube, 151
Floats, 151
Flotation method, calcium chloride, 317
Flowage of streams, abbreviations for, 72
  data for rod floats, 154
  Embody's formula for, 153
  volume of, 153
Foerst centrifuge, 256
Formalin, 254, 271
  defects of, 269
Formol-alcohol, 271
Forms, tabular, field records, 7, 11, 16, 42, 54, 166
  for ocular micrometer, 284
  for plankton records, 290
Fox and Wingfield, 211
Frustrum of cone, formula for, 345

G

Gage, hook, 62
  metal staff, 64
  staff, 63, 64
  Stevens anchor, 63
  water-streak, 64
Geological Survey, U S, color outfit, 138
  turbidity rod, 128
Geometrical figures, area by, 88
Glass, colored standards, 219
  diffusing, 162
  electrode, 223
Glass-disk method, 138
Glass electrode, 223

Glass slide racks, 260
Gradient, oxygen, 213
Gravimetric method, bottom fauna, 304
  periphyton, 329
  plankton, 295

H

Hensen-Stempel pipet, 281
Hess, circular sampler, 323
  vegetation method, 332
Hook gage, 62
Hutchinson, 213
Hydrogen gas electrode, 223
Hydrogen-ion concentration, color charts, 217
  colored-glass standards, 219
  colorimetric methods, 217
  comparators, 220
  electrometric methods, 217
  indicators, 220
  solution standards, 218
  test papers, 220
Hydrographic mapping, 1
  construction of maps, 68
  essential information, 68
Hydrographic maps, sources of, 356
Hypsographic curve, direct and percentage, 94

I

Ice, sounding on, 32
Ice drill, 362
Identification of plankton, 268, 269, 270
Improvised instruments, for measuring angles, 48
  plane table, 48
Index, thermometer, 102
Index figure for shore line, 93
Index limnograph, 155
Indicators, 220
Inflowing water, 71
Ink, colored, 70
  Higgins Eternal, 233
  Higgins Waterproof, 233
Instruments, improvised, 47
  reading of, xiii
Interior angle, 5
Irwin, sampler, 204
  strainer, 205
Isaacs, 212

J

Jackson turbidimeter, 130
Johnson and Whitney, 212
Juday, Birge and, 167, 239
  plankton trap, 242

K

Kemmerer sampler, 199, 231
Kindale, 193
Kits, field, 359
  chemical, 360
  instrument, 360
  sample bottle, 360

L

Lagoons, methods for, 20
Lakes, area, 79
  direction of major axes, 78
  heat budget of, 121
  location of, 357
  maximum depth, 78
  maximum depth-surface relation, 78
  maximum effective length, 78
  maximum effective width, 78
  maximum length, 77
  maximum width, 78
  mean depth, 78, 122
  mean depth-maximum depth relation, 78
  mean temperature of, 122
  mean width, 78
  volume of, 95
  warming by wind, 124
Lansberg, 173
Leads, sounding, 25
Length, equivalent values, 341
Length of lakes, maximum, 77
  maximum effective, 78
Length of streams, 97
Levels, water, 61
Light penetration, 159
  methods of measure, 160
  record form, 166
  units of, 163
Limit of visibility methods, 159
Limitations, inherent, ix
Limnograph, index, 155
Linen, 233
Lines, 337
  combination, 339
  for heavy equipment, 340
  graduated, 337
  metal, 339
  small, 340
  sounding, 25
Literature on plankton, 367
  general works, 367
  phytoplankton, 367
  zooplankton, 368
Littoral areas, analyses of samples, 317
  distribution of samples, 316

Littoral areas—(*Continued*)
methods for, 311, 319
sampling equipment, 311
Low-water datum, 69

M

Major axes of lakes, 78
Map, colors, 69
construction, 67
measurer, 79, 90
Mapping, 1
aerial photographic, 48, 59
Maps, 1
construction of hydrographic, 68
enlargement of, 77
symbols on, 74
Mark, bench, 61
Marking of equipment, xii
duplicate, xiii
Marl bottoms, 320
Mathematical formulas, 344
Maucha, 213
Maxim pressure plate, 172
Maximum-minimum thermometer, 101, 102, 118
advantages and disadvantages, 120
correction of, 119
limitation, 120
precision, 120
storage of, 121
Mean temperature, computation of, 122
Mechanical current meters, 147
Price pattern, 147
Meter, Ekman current, 149
mechanical current, 147
transparency, 136
Meter sticks, 67
Meters to feet, 347
Methods, biological, 229–333
chemical, 197–227
choice and application of, ix
physical, 99–196
Methyl orange alkalinity, 215
Microammeters, 161
Micrometers, Whipple ocular, 279, 282
Micro-Winkler method, 211
Middleton, 169
Miller, Thompson and, 211
Moon sorting trough, 319
Moore, 181, 182, 184, 185
Morphometry, 1, 77–98
Movement, water, 141

N

Nannoplankton, 255, 275
Neel, 324
Negretti and Zambra thermometer, 103
Net plankton, 232
Nets, Birge cone, 236
care and repair of, 253
closing, 246
coefficients, 278
linen, 233
pattern for plankton, 234, 239
plankton, 232
tow, 237, 309
types of plankton, 239
wire, 234
Wisconsin, 239, 240

O

Ooze sucker, 181, 299
Ostracoda, literature on, 370
Oxygen, dissolved, colorimetric, 212
deficit, 212
effect of temperature, 352
gradient, 213
micro-Winkler method, 211
Rawson's nomogram, 366
Rideal-Stewart method, 207
sampling of, 206
Winkler method, 207
Oxygen deficit, absolute, 212
actual, 212
Oxygen gradient, 213

P

Pantograph, 77
Paper, mapping, 67
Pastes, 64
Pattern, for plankton nets, 234
for tow nets, 239
Peat borers, 185
Pennak, 324
Periphyton, analyses of samples, 328
gravimetric method, 329
methods for, 327
numerical methods, 328
volumetric method, 329
Perley, 220, 223
Permanent mounts for plankton, 269
Peters, Williams and Mitchell, 214
Petersen dredge, 178, 308, 312
Pettersson, *et al*, 161
Phenolphthalein alkalinity, 215
Photographic mapping, aerial, 48
of streams, 59
Photometers, 161
Photronic cell outfit, 161
standardization of, 163
Physical methods, 99

Phytoplankton, literature on, 367
Pins and thread method, 92
Pitot tube, 141, 170
  Darcy's modification, 142
  improved, 142
  modern simple form, 143, 144
Plane table, improvised, 48
Plane-table survey, 17
  procedure, 18
  traverse of streams, 56
  with graduated tape, 34
  with stadia rod, 34
Planimeter, corrections and adjustments, 79
  hatchet, 82
  polar, 79
  testing rule, 80
  trial disk, 80
Plankton, 231
  analyses of concentrates, 279
  areal standard-unit method, 290
  care and repair of nets, 253
  catalog, 271
  centrifuges, 255
  Clarke's sampler, 249
  closing net, 246
  collecting apparatus, 231
  cubic standard-unit method, 292
  differential count, 289
  directions for counting, 287
  drawings and measurements, 270
  filter-paper method, 263
  filters, 262
  gravimetric method, 295
  identification, 268
  identification records, 269
  Juday trap, 242
  literature aids, 367
  mounting of, 269
  nanno-, 255
  nets, 232
  permanent mounts, 269
  preserved, 269
  qualitative methods, 267
  quantitative methods, 272
  samplers, 231
  sand-filter method, 263
  settling method, 254
  sling-filter method, 263
  survey count, 285
  total count, 286
  trawl, 359
  types of nets, 239
  volumetric methods, 296
Plankton trap, Clarke's modification of, 245
  Juday, 242
Plankton trap—(*Continued*)
  operation of, 242
  procedure, 276
Plant-inhabiting organisms, methods for, 327, 330
  washing method, 331
Platinum-cobalt method, 137
Platinum-wire method, 127
Plotting of field data, 6, 12, 16, 21, 23, 24, 30, 32, 33, 35, 38, 46, 55
Pole, sounding, 26
Ponds, methods for, 20
Poole, *et al*, 161
Preservatives for plankton, 269, 271
Pressure-plate anemometer, 171
Pressure-tube anemometer, 170
Profiles, construction of, 94, 95
  depth, 52
Profundal bottom, methods for, 299
  qualitative methods for, 299
  quantitative methods for, 300
Propeller anemometer, 169
Protozoa, literature on, 368
Protractors, 67
  checking accuracy of, 67
  three-arm, 46, 67
Psammolittoral areas, analyses of samples, 324
  methods for, 323
Pump and hose method, 201, 231

Q

Qualitative plankton methods, 267
Quantitative plankton methods, 272
Quinhydrone electrode, 223

R

Racks, glass-slide, 260
Ranges, 34, 47
Rating of sieves, 188
Rawson, 181
  nomogram, 209, 366
Reading of instruments, xiii
Recorders, graphic water-level, 61
Recording of data, xiv
Reighard dredge, 309
Reserve pH, 222
Resistance, thermal, 123
Reversing thermometer, 103
  care of, 111
  case for, 105
  corrections for, 106
  defects and adjustments, 108
  frame for, 109
  functional errors, 106
  propeller frame for, 106

Reversing thermometer—(*Continued*)
structural errors, 106
testing of, 111
Ricker, 231, 248, 274
Rideal-Stewart method, 207, 209
Ripple-mark records, 193
Ropes, graduated, 337
Rotifera, literature on, 369
Rule, average ordinate, 90
Simpson's, 88
testing, 80
Rulers, parallel-line, 67

S

Sampler, 199
bottom, 175
Clarke's plankton, 249
combination, 241
deep-core, 186
Dendy inverting, 315
Ekman dredge, 176
exploratory, 175
Hale's, 202
Hess circular, 323
Irwin's, 204
Kemmerer, 199, 231
ooze sucker, 181
peat borers, 185
plankton, 231
scoop, 175
stream-bottom, 321
unit-area, 311
vertical core, 182
water, 232
Wilding's square-foot, 312, 323
Young's periphyton, 327
Samples, analyses of bottom, 303, 323
dried, 190
final, 190
quartering, 189
preparation of field, 189
size of, 190
wet, 190
Sampling, bottles, 206
bottom, 186
chemical, 201, 202, 204, 205, 206, 231
day and night, 274
dispersed random, 316
procedures for plankton, 274
qualitative plankton, 267
quantitative plankton, 272
seasonal plankton, 273
transect, 316
vertical, 273
Sampling stations, symbols representing, 73
Sand filter for plankton, 263
Scales, Beaufort wind, 172, 173
wind, 172, 173
Scoop sampler, 175
Scott, 123
vane method, 154
Screens, care of, 189
general utility, 186
Seasonal sampling, plankton 273
Secchi disk, 159
Sections, numbering of, 257
Sedgwick-Rafter, counting cell, 280
filter method, 265
Sediments, Wentworth classification of, 353
Seiches, detection and measurement of, 155
Selenium rectifier cells, 162
Settling method, 254
Sextant, corrections and adjustments, 40
description of, 39
index error of, 40
sounding with, 38
Shading, descriptive abbreviations, 72
Shore development, 93, 94
Shore line, dividers method, 93
index figure, 93
length of, 90
map-measurer method, 90
pins and thread method, 92
surveys, 3
Sieves, openings and mesh of, 354
rating of, 188
testing, 187
Signals, flag, 15, 18, 28, 29, 38
shore, 45
Simpson's rule, 88, 89, 90
Sling filter, Whipple, 263
Slope of basin, 96, 97
Sodium thiosulfate, standardizing of, 208
Sorting trough, Moon's, 319
Sounding, by simultaneously measured angles, 27
by transit and stadia rod, 30
in streams, 58
leads, 25
methods of, 27
oar-stroke method, 47
on ice cover, 32
plane table and ranges method, 36
pole, 26
time-interval method, 47
weights, 26
with sextant, 38
Sounding lines, 25
types, 337–339
Soundings, 25

Sphere, formulas for, 344
Spilhaus, 112
Stadia constant, 9
Stadia rod, 6, 30, 32, 34
Stadia survey, 8
  errors of, 9
  field records, 11
  plotting, 12
  procedure, 9
Staff gage, 63, 64
Standard unit, areal, 291
  cubic, 292, 294
Standard weights, xii
Standards, xi
Still well, 62
Storage of equipment, xvii
Strainer, Irwin's, 205
Stream surveys, additions to, 59
  deflection-angle traverse, 51
Streams, aerial photographic maps of, 59
  bottom sampler, 321
  bottom samples, analysis of, 323
  bottoms, 320
  descriptive abbreviations, 72
  drift, 359
  length, 97
  location of, 357
  other measurements, 98
  soundings in, 58
  Surber's sampler, 321
  volume of flow, 153
  width, 97
Sublittoral bottoms, methods for, 308
Subsurface temperature, 103, 120
Surber's bottom sampler, 321, 331
Surface temperature, 101
Survey, addition to lake, 49
  by enclosing rectangle, 23
  by simultaneously measured angles, 12
  by transverse measurements, 21
  by triangles, 20
  plane-table, 17
  plotting of, 16
  shore-line, 3
  stadia, 8
  stream, 51
  traverse, 3
  U S Coast and Geodetic, 61
  U S Geological, 61, 62
Survey count, bottom organisms, 303
  plankton, 285
Symbols, duplicating of, 74
  for aquatic plants, 74, 75
  for physical features, 72, 73
  for sampling stations, 73
  for vegetation, 73

T

Table, drawing, 67
Tables, 341-355
  aperture size of bolting cloth, 355
  Centigrade to Fahrenheit, 348
  dissolved oxygen and temperature, 352
  equivalent values, 341
  Fahrenheit to Centigrade, 349
  feet to meters, 346
  mathematical formulas, 344
  meters to feet, 347
  openings and mesh of sieves, 354
  silk bolting cloth, 353
  temperature and density of water, 350
  Wentworth's classification of sediments, 353
  Wild's plate and wind velocity, 355
Tabular forms, xiv
Tape, 33
  graduated, 34
Telescopes, water, 363
Temperature, 101
  Centigrade to Fahrenheit, 348
  density of water, 350
  Fahrenheit to Centigrade, 349
  mean, of lakes, 122
  relation to dissolved oxygen, 352
  standards, xii
  subsurface, 103, 120
  surface, 101
Terms, abbreviations, 71
  descriptive, 71
Test papers, for pH, 220
Test plates, 67
Testing sieves, 187
Thermal resistance, 123
Thermographs, 112
Thermometer, case for reversing, 105, 109
  corrections for reversing, 107
  electric-resistance, 117
  maximum-minimum, 101, 102, 118
  Negretti and Zambra, 103
  reversing, 103
Thermophone, 112
Thompson and Miller, 211
Thrupp method, 149
Total count, plankton, 286
Tow nets, 237, 309
  pattern for, 239
Township, numbering of sections, 357
Transects, beach, 324
  bottom-fauna, 309, 316
  line, 317
  plankton, 272
  zonal or belt, 317

Transit, 3, 30, 32, 33
Transparency meter, 136
Trapezium, formula for, 344
Trapezoid, formula for, 344
Traverse survey, 3
  deflection angle for stream surveys, 51
  field records, 7, 54
  plane-table traverse, 56
  plotting of, 6
Trawl, plankton, 359
Tray method, 319
Triangle, formulas for, 344
Triangle bottom dredge, 310
Tube, Bentzel velocity, 145
  Darcy's, 142
  Pitot, 141, 142, 170
Tubificidae, 305
Turbidimeter, Baylis, 136
  Hellige, 132
  Jackson, 130
Turbidity, methods of measure, 127, 136
  platinum-wire method, 127
  silica standards, 127
  unit of measure, 127
  U S Geological Survey rod, 128
Turbidity rod, 128
Twenhofel and Tyler, 188, 193
Tyndall effect, 132, 134

U

Unit-area sampler, 311
Utterback, *et al*, 161

V

Vane, Scott's, 154
Velocity, current, 141
  estimations of wind, 172, 173
  Thrupp method, 149
  tube, Bentzel, 145
  wind, 169
  Wild's plate and, 355
Vertical sampling, plankton, 273
Visibility, limit of, 159
Volume, curves, 96
  development, 95, 96
  equivalent values, 342
  flow of streams, 153
  of lake, 95
  standards, xii
Volume curves, 96
Volume development, 95, 96
Volumetric method, bottom organisms, 304
  periphyton, 329
  plankton, 296

W

Wagon recorder, 157
Warren and Whipple, 112
Water, density of, 350
  descriptive abbreviations, 71
  movement of, 141
Water levels, 61
  graphic recorders, 61
Water telescopes, 363
Water-streak gage, 64
Wax pencils, 69, 70
Weight method for area, 85
Welch, 274
Well, still, 62
Wentworth, classification of sediments, 353
  grade scale, 354
Weston cell, 161, 167
Whipple, ocular micrometer, 279, 282
  sling filter, 263
  Warren and, 112
Whitney, 136
Whitney, Johnson and, 212
Width, of lakes, 78
  of streams, 97
Wilding's bottom sampler, 312, 323
Wild's plate, 172, 355
Wilson, 186
Wind, Beaufort scale, 172, 173
  scales, 172, 173
  velocity, 169
  velocity estimations, 172, 173
  warming of lake, 124
  Wild's plate, 355
Windikator, 171
Wingfield, Fox and, 211
Winkler method, 207
  micro-, 211
Wire cloth, 234
Wisconsin, large net, 241
  plankton net, 239, 240
  small net, 239, 253
  trap, 330
Work of wind, 124

Y

Young, counting cell, 328
  periphyton sampler, 327